MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

REPORT
for year 1952

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ASSOCIATION LIMITED

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PREFACE

By J. Stewart-Wood, Esq., *Chairman*

As mushroom prices fell from the luxury scale to the commercial plane many of us in the Industry were temporarily frightened for the future, and on starting to cut down our costs wondered why we should support what might quite well be a failing Research Station. It became more and more difficult to get response to the appeals sent out from Yaxley, and but for the most generous help of our friends in the Ministry of Agriculture, we should have been unable to continue the most valuable work being done by Dr. Edwards and his assistants.

It was very heartening for me when the appeal I sent out last year received such magnificent support. I would like to thank again all those who responded.

It seemed to me, as a grower myself, that more growers were beginning to realise that Research is a necessity. I think it should be regarded as an integral part of our business if we are to progress; and let us by subscribing each year what we, individually, think is a fair sum show the Ministry of Agriculture that we are really interested, and that we want to have a say in what is being done, even when they take over full responsibility.

Owing to the acute shortage of manure and the increase in price, synthetic compost is being more widely used. Those who use it entirely say that they would not return to stable manure. What more could be said for it?

There is much excitement being aroused by the work being done on synthetic soil for casing. It is hoped to discover a really practical medium to work with.

The disease room is now in operation and many problems of disease control are being tackled.

The Mushroom Industry is here to stay and let us see to it that Research has its rightful place, to further efficiency in cultural methods, thereby making production more economical.

J. STEWART-WOOD,
Chairman, 1952.

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GENERAL REPORT

During the past year the study of casing soil has been extended from the laboratory examination of soils and some artificial mixtures to their use on mushroom beds, on a small scale. This development will continue in 1953.

Laboratory tests have been used to study the factors limiting diffusion of gases through a layer of soil, in order to assess the importance of soil structure and pore space in the casing soil on a mushroom bed. The relation between rate of diffusion of a gas and the proportion of pore space in the soil layer, which had previously been reported by other research workers, was confirmed for soil as used in mushroom growing. It was also found that when the soil was wet, and the water present filled up part of the pore space which in dry soil would be available for diffusion of gas, the rate of diffusion was cut down in proportion to the water present. Soils made up of uniformly large lumps have more pore space than finer soils, and therefore allow freer passage of gases.

A further study on carbon dioxide production in mushroom compost during cropping has confirmed earlier estimates of the rate of production. On comparing this with the concentrations observed inside the beds by other workers, and with the rates of diffusion observed in layers of casing soil, satisfactory agreement was reached, and the following points have now been established.

Unless the carbon dioxide which is produced continuously in the bed escapes, it will build up a high concentration which may be directly or indirectly harmful to the mushroom. The rate of escape by diffusion through the casing soil depends on the concentration of the gas present in the bed, and on the thickness and proportion of pore space of the soil layer. The work reported here has shown that under normal conditions the possible rate of diffusion through a reasonably open textured soil is quite sufficient to remove all the carbon dioxide as fast as it is produced, without reaching a high concentration in the bed. Watering fills up some of the pore space and so reduces the rate of diffusion. Even then under good conditions no harm would be done. However, the figures obtained show that the combination of a soil with low pore space (most probably one with a high proportion of fine particles), heavy watering to fill up the pores with water, and a high temperature to increase carbon dioxide production, can cause a high concentration to develop in the bed. The point at which carbon dioxide becomes toxic is not known, but high concentrations also reduce the oxygen available; any other gas produced by the mushroom would behave in a similar way.

Apart from this rather uncommon aspect of the work in explaining a possible cause of trouble, it is important as a contribution to our understanding of the function of casing soil, which has for so long been almost a complete mystery.

It is difficult to discuss the cropping experiments on casing soil at all profitably at this stage. There is some indication that peat-sand or peat-vermiculite mixtures may be suitable for commercial use, but so much remains to be learned about their cost, preparation, management on the beds, and yields that the outlook is very uncertain. Some further experiments on the use of these mixtures will be carried out in 1953, but the long term study of casing soil will be continued.

In two other experiments, omission of potassium sulphate made no difference to the yield from synthetic compost, and the potassium requirement must have been supplied in full by the straw used. Similarly an extra turn in the middle of the last week of composting had no effect on yield. The benefit of thorough shaking was confirmed although by a very small margin.

An attempt to " short-compost " synthetic compost gave a lower yield than was obtained from the normal 4-week period.

Another attempt to compare the yields from systematic picking of closed and open mushrooms showed no final difference, although the weight of " flats " was greater during the first few weeks.

Advisory work on pests and diseases has continued and more samples of casing soil have been received. The number of samples infested with eelworms has increased. In a series of experiments with various chemicals, a chlorophenol preparation was the most effective for killing eelworms. Heating at 55° C. (131° F.) for 24 hours killed all the eelworms in compost, showing that an efficient peak-heat destroys them. The use of copper sulphate for prevention of Truffle, suggested for commercial trial by laboratory experiments, has given good results on some farms where Truffle was previously found in almost every crop. It is completely ineffective when spawn is run even for a few days at or near 80° F., but it has reduced Truffle to an insignificant amount when lower temperatures were maintained. The effective temperature limit and the possible effect of any other conditions are still unknown. Experiments on this aspect are still in progress.

The failure of our first attempt to infect mushrooms with *Dactylium* and *Mycogone* (see p. 44) emphasises, not for the first time, the importance of air conditions in determining incidence of disease; at the second attempt *Mycogone* developed, but even then *Dactylium* did not. A similar observation was made several years ago when spores of *Verticillium psalliotae* were found in the air and on the casing soil of beds in crop, without any mushrooms being attacked. The temperature then was below 15° C. (59° F.) and the R.H. was usually below 80%. While low temperatures and humidities are not conducive to high yields, they can help materially to combat disease, with or without the help of fungicides and other measures. Spraying the casing soil with zineb and thiram reduced the attack by *Mycogone* and *Verticillium*, but when these fungicides were mixed with the soil before casing they were ineffective at the levels used.

It is a pleasure to express our thanks to the many individuals and firms who have helped us in various ways during the year; to Mr. F. C. Atkins, Mr. B. A. Noble, and Messrs. Noble Mushrooms Ltd. for help with experiments on disease; to Mr. M. C. Luxmoore for lending machinery; to Messrs. Murphy Chemical Co. Ltd., Plant Protection Ltd., Monsanto Chemical Co. Ltd., American Cyanamide Co. Ltd., J. E. R. Simons Ltd., British Alkaloids, Ltd., and H. Mount & Son for gifts of mushroom spawn and chemicals; to Mr. E. R. Hoare and the National Institute of Agricultural Engineering, and to Mr. F. A. Evans for the loan of instruments; and to many mushroom growers who have carried out commercial trials at our request, and have helped us in other ways.

CHEMISTRY DEPARTMENT

P. B. Flegg

Work on composts has been restricted to the completion of an investigation on changes in nitrogen distribution in dried blood and urea composts. Last year the effect of watering and the presence of mycelium on soil structure, stability, and porosity was described. This work has been extended by measurement of the rate of diffusion of gases through soils in relation to their pore space and the effects of aggregation and the presence of water. Several other aspects of soil water holding capacity, porosity and related properties have also been investigated.

The advisory work of the department has increased slightly; altogether over 60 enquiries were answered.

Composts

Nitrogen changes in urea and dried blood composts (Experiment 18) during composting were discussed in the last report. These composts were analysed again at the end of the cropping period and the results are shown in Table 1. So that changes from first turn to emptying may be readily seen, the results have been represented graphically, Figure 1.

Although at the first turn the relative proportions of ammonia-, nitrate- and organic-N in the dried blood and urea composts differed considerably, at emptying the relative proportions were very similar. Despite the initial differences in nitrogen distribution the composts tended to become similar in composition. This trend is apparent even at the end of composting where an initially high ammonia-N content in the urea stacks has decreased and a low initial ammonia-N in the dried blood composts increased. This tendency to reach a similar nitrogen distribution is of interest when it is considered that dried blood and urea have consistently produced equally satisfactory yields in the past (Edwards, 1952).

The total amount of nitrogen present at filling and emptying was greater in the dried blood compost than in the urea compost. This is in accordance with previous results and may be of importance when considering the manurial value of spent synthetic composts (Flegg, 1952).

Nitrate-N was too low to be determined accurately during composting, but during cropping it increased to 6—8% of the total nitrogen present. Indications that accumulation of nitrate in the compost occurred during the several stages of mushroom growing have been reported previously (Burrows & Flegg, 1951). However, there was no indication that the accumulation of nitrate in the beds was related to cessation of fruiting.

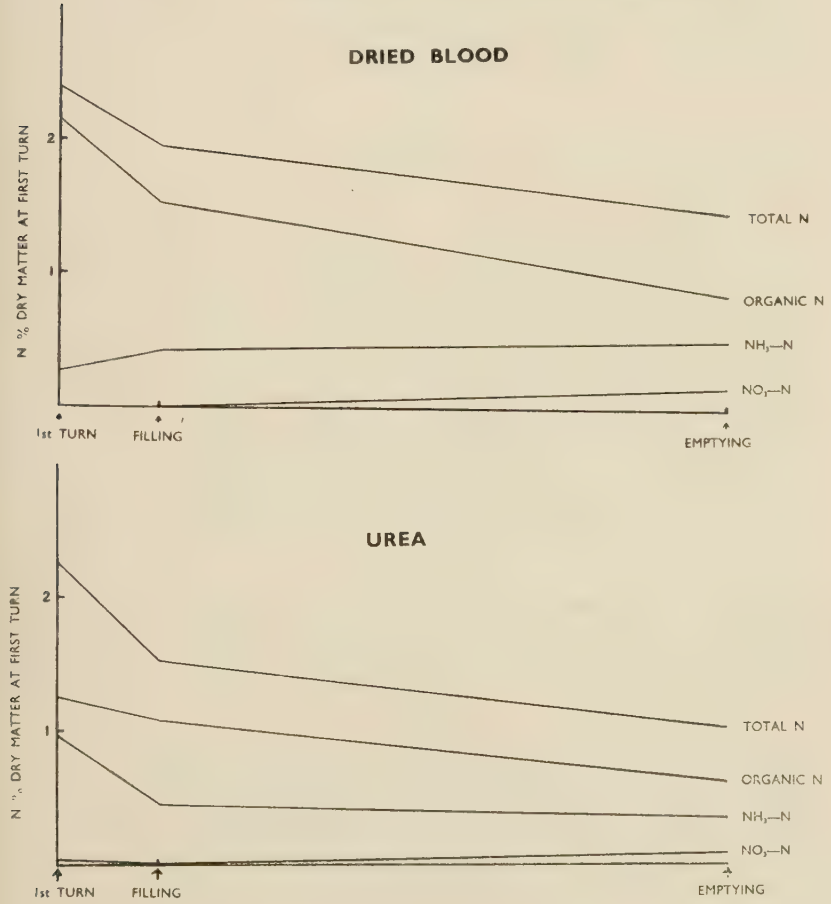
REFERENCES

Burrows, S. & Flegg, P. B. (1951). A.R. Mushroom Res. Stat. 1950.
Edwards, R. L. (1952). A.R. Mushroom Res. Stat. 1951.
Flegg, P. B. (1952). A.R. Mushroom Res. Stat. 1951.

Table 1. Experiment 18. Distribution of nitrogen at emptying
(N as % dry matter at 1st turn)

N Distribution	Dried Blood Compost (means of 6 beds)	Urea Compost (means of 6 beds)
Ammonia—N	0·50	0·35
Nitrate—N	0·12	0·06
Organic—N	0·82	0·60
Total N	1·44	1·01

Figure 1—N distribution from first turn to emptying



CASING SOIL

P. B. Flegg

The importance of the permeability of the soil layer and the effect of soil pore space, structure, and stability upon permeability was discussed in the last report. The effects of watering and the presence of mushroom mycelium on soil structure and stability were also investigated and discussed. Work on these aspects of the function and properties of casing soils has been continued by an examination of the rates of diffusion of gases and vapours through soils and other porous media and of the rate of production of carbon dioxide by mushroom composts.

Diffusion of gases and vapours through soils

The relationship between the diffusion of a gas through a porous medium (D), the diffusion coefficient of the gas through air (D_0), and pore space of the medium (S), has been investigated by Buckingham (1904), Penman (1940 a & b) and others. The relationship:—

$$\frac{D}{D_0} = 0{\cdot}66\ S$$

has been found to hold for pore space up to 65%. The range of soil pore space likely to be encountered in mushroom casing soils is between 40 and 70%.

However, in previous work very little account has been taken of the degree of aggregation of the materials used. Usually they were in a fine state of division. The effect of aggregate size on this relationship was uncertain and it was necessary to investigate the effect of aggregation and of the presence of water upon the diffusion of gases and vapours through soils. This work has been fully reported elsewhere (Flegg, 1953). The conclusions reached were:—

1. Using ether and acetone the diffusion coefficient (D) of gases through soils has been determined over the range of soil pore space to be expected in agricultural practice and a relationship between (D), (D_0), and (S) was obtained which is in good agreement with previous work, (Penman, 1940 a & b) and (Bavel, 1952). See Figure 2.

2. No differences in this relationship due to aggregate size in the range from <2 mm. to 12·5—25 mm. diameter were found; changes in rate of diffusion through soils of varying particle size were fully accounted for by the resultant changes in pore space.

3. The effect of wetting soils of three aggregate size ranges has been investigated and the reduction in diffusion through soils (D) was related directly to the moisture present, irrespective of aggregate size, except where the original soil packing was disturbed by relatively large cracks in the soil due to shrinkage on drying. Fig. 3.

Contd. on page 12

Figure 2—Relationship between rate of diffusion $\frac{D}{D_o}$ and pore space with soils of different aggregate sizes compared with previous observations

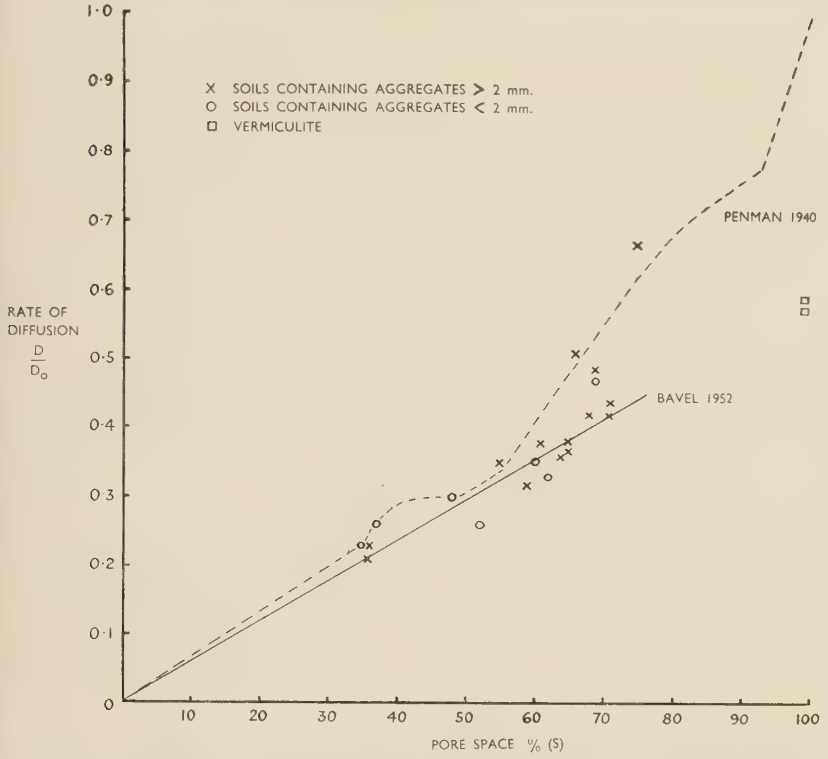
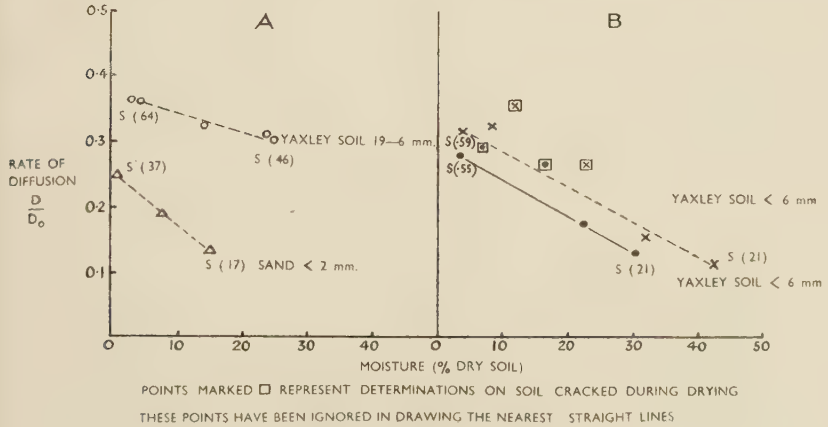

X SOILS CONTAINING AGGREGATES > 2 mm.
O SOILS CONTAINING AGGREGATES < 2 mm.
□ VERMICULITE
PENMAN 1940
BAVEL 1952
RATE OF DIFFUSION D/Do
PORE SPACE % (S)

Figure 3—Effect on rate of diffusion of the presence of moisture in soil



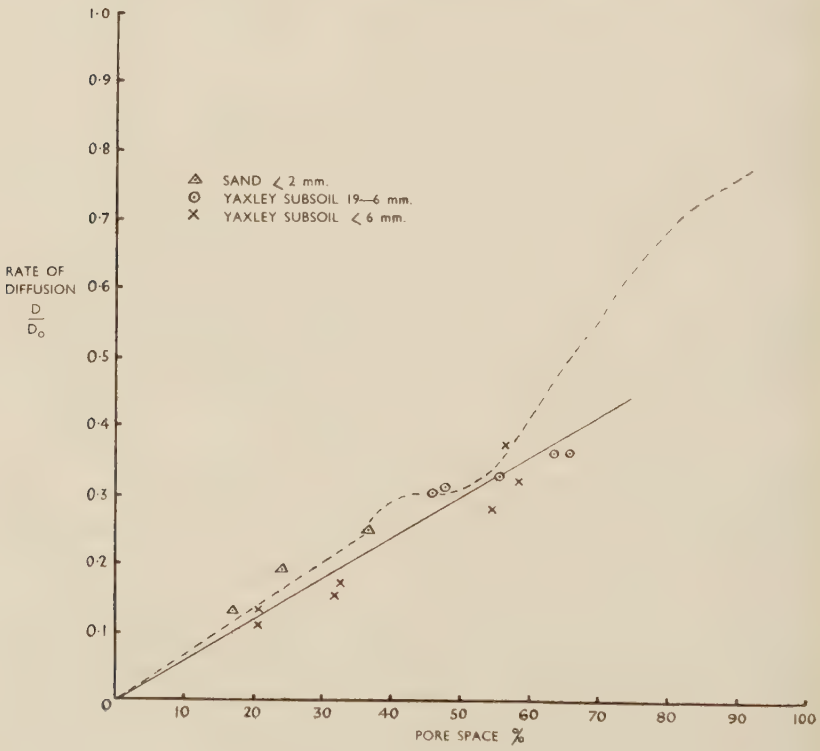
POINTS MARKED □ REPRESENT DETERMINATIONS ON SOIL CRACKED DURING DRYING
THESE POINTS HAVE BEEN IGNORED IN DRAWING THE NEAREST STRAIGHT LINES

4. When the reduction in soil pore space caused by the presence of water is calculated, the results obtained from wet soils agree fairly well with the curve obtained for air dry soils. Thus over the range covered by the experiments the reduction in (D) due to the water in the soil was approximately proportional to the reduction in pore space due to the volume of water present. Figure 4.

On the basis of this and previous work (Penman, 1940, a & b) it has been possible to calculate the rates of diffusion of carbon dioxide through 1″ and $1\frac{1}{2}$″ layers of casing soils with pore spaces representing soil before and after watering, with several concentrations of carbon dioxide in the bed. These are shown in Table 2.

Figure 4

Relation between rate of diffusion $\frac{D}{D_0}$ and pore space of three soils when pore space was altered by varying moisture content



It is assumed that the carbon dioxide concentration in the air in the house, normally 0·03%, is negligible. If the carbon dioxide concentration in the house is much greater than this, allowance must be made when estimating the concentration difference between compost and air in Table 2.

Carbon dioxide production and concentration in mushroom beds

In order that the previous calculations can be referred to actual conditions in the mushroom bed, some estimate of the rate of production of carbon dioxide and of the concentrations found in mushroom beds is required.

From an experiment using 580 g. of fresh compost by Burrows (1949) it has been possible to calculate the average rate of production of carbon dioxide per square foot. Taking into account carbon dioxide produced by mushrooms, a mean output of 120 ml. carbon dioxide per square foot per hour is obtained.

Burrows (1949) also calculated carbon dioxide production from dry matter losses in a typical mushroom bed, obtaining a mean rate of 130 ml. carbon dioxide per square foot per hour. Measurements have also shown that the rate of production of carbon dioxide at the end of cropping is of the order of 35—45 ml./hour.

Table 2.

Rates of Diffusion of CO_2 through 1″ and 1½″ layers of soil at pore spaces representing dry (S=50%) and wet (S=10%) soils at several concentration differences.

Concentration Differences	Volume (ml.) of CO_2 passing through 1 square foot of soil per hour.	
% CO_2	1″ Soil layer	1½″ Soil layer
Pore Space 50% (dry soil)		
0·2	127	85
0·4	255	170
0·5	318	212
1·0	637	425
1·5	955	637
2·0	1,270	850
5·0	3,180	2,120
Pore Space 10% (wet soil)		
0·2	27	18
0·4	54	36
0·5	67	44
1·0	134	89
1·5	201	134
2·0	268	178
5·0	669	446

More recently, from 350 g. wet spawned synthetic compost kept in jars in an incubator at 25° C. the carbon dioxide produced was found to vary from 135—160 ml. per square foot per hour 7 days after peak heating, to 20—45 ml. per square foot per hour 23 days later.

Thus from the results obtained by two different methods, from actual measurements of carbon dioxide produced by small samples of compost and from calculations based on dry matter losses in compost on shelf beds, an average rate of carbon dioxide production is 120—160 ml. per square foot per hour, decreasing to 20—50 ml. as the compost becomes exhausted. These are only average figures and it is possible that at times the rate of production may be much higher.

The concentration of carbon dioxide found in composts has been measured by Stoller (1936) and Lambert (1933) and was found to be between 0·2 and 0·4% before watering, and about 2·0%, sometimes up to 5·0% after watering. Stoller attributes this increase in concentration to an increased production of carbon dioxide by the micro-organisms due to the addition of water, but it seems more likely that it is an accumulation in the compost due to a lowering of soil pore space, and hence a lowering of the rate of diffusion of carbon dioxide, by watering the soil. A dry soil has about 40—60% pore space but after a fairly heavy watering it is reduced to about 10—20%.

From Table 2 it can be seen that when equilibrium is reached the carbon dioxide concentration in the compost, required for the passage of 120—170 ml. per square foot per hour through $1\frac{1}{2}''$ of dry soil (50% pore space) is 0·3 to 0·4%. This agrees very well with the concentrations found by Stoller in composts under soil before watering. The rate of production of carbon dioxide would have to be over 400 ml. per square foot per hour for a concentration of 1% in the compost to be reached.

The effect of watering a soil is to reduce the pore space by an amount approximately equal to the volume of water added, irrespective of degree of aggregation of the soil (Flegg, 1953). A clay loam soil when watered to approximately its full capacity has 10—20% pore space, see Fig. 3.

From Table 2 it can be seen that at 10% soil pore space, to maintain a rate of diffusion of 130—170 ml. carbon dioxide per square foot per hour the concentration in the compost must be 1·5% to 2·0% and at 400 ml. per square foot per hour it must be nearly 5·0%. These figures also agree with the actual measurements by Stoller (1936) of carbon dioxide concentration in the compost after a heavy watering.

Thus from the collected data the amount of carbon dioxide produced by compost in the bed is about 150 ml. per square foot per hour and the transfer of this gas through the soil to the atmosphere above the beds can be accounted for solely by the diffusion through the soil layer. This explains the high concentrations of carbon dioxide found by Stoller in the compost just after watering the soil, and the low concentrations found when the soil was practically dry. However this does not preclude the possibility of other mechanisms of gaseous interchange.

The effect of carbon dioxide on mycelial growth

The effect of carbon dioxide in the compost on mycelial growth and fruiting is uncertain and there is little experimental evidence. Stoller has found a slight tendency for mushrooms to grow larger and even of a stimulus to fruiting by a high concentration of carbon dioxide in the compost. Lambert on the other hand found no significant differences in yield of mushrooms when the concentration in the compost was between 6 and 9%.

Uncertain as the effect of carbon dioxide in the compost on fruiting and yield may be, even less is known about its effect on the growth of the spawn during the time from spawning to pinhead formation. Stoller found that when carbon dioxide was allowed to accumulate in spawned compost at certain levels the rate of accumulation was slowed down or ceased and the concentration remained steady. The concentration reached at 50° F. was 6·5%, and at 71° F. 16·5%. It is possible that at these temperatures the concentration of carbon dioxide was toxic to further microbial action in the compost and hence the concentration remained steady. The lower toxic concentration at 50° F. than 71° F. might be due to the increased solubility of carbon dioxide at lower temperatures. If this is so a similar toxic action on growing mycelium may be produced in a compost cased with a soil of low initial pore space and kept fairly moist.

Work on the effect of several concentrations of carbon dioxide on mycelial growth is proceeding in conjunction with the Microbiology Department. So far it has been observed that in the absence of carbon dioxide (over caustic soda) the rate of growth of mycelium is consistently slower than when it is present. Thus it would seem that some carbon dioxide at least is necessary for optimum mycelial growth.

Pore space, aggregate size, and degree of settling

In view of the effect of soil pore space on the rate of diffusion of gases through the casing soil the relationship between aggregate size, settling, and soil pore space was investigated. Although aggregate size in itself only affects the rate of diffusion of gases through variations in soil pore space, a soil consisting of small aggregates can be packed more tightly than the same soil with large aggregates, thus altering the pore space of the soil layer, and with it the rate of diffusion of gases.

Dry Yaxley clay loam was separated into several aggregate sizes by means of sieves. 200 ml. of each fraction was then poured into a measuring cylinder. The cylinder was then tapped firmly on the bench and the volume noted after every 10 taps. Tapping was continued until the volume of the soil remained constant. Duplicates agreed well both in weight of soil to make up the original 200 ml. and in final volume after compaction. The pore space was calculated for each soil before and after compaction. Fig. 5 shows that the smaller the soil aggregates the lower the final pore space after settling. The pore space of the soil made up of large aggregates (25·4—6·3 mm.) decreased from 73 to 69% but that of the soil containing smaller aggregates (<0·15 mm. passing 100 mesh B.S.S.) decreased from 65 to 54%.

Several mixtures of the soil of different aggregate sizes were then made and the tapping procedure repeated. The results are shown in Fig. 6. In the three series of mixtures used where the proportion of coarser to finer aggregates was 1 : 3 or 1 : 1 the pore space after settling was less than for either coarse or fine soil alone. Mixing small and large aggregates results in greater settling being possible than if the soil aggregates were of more or less uniform size. Thus to prevent reduction in soil pore space by settling during casing, uniformity of aggregate size may be more important than the proportion of larger aggregates.

Figure 5—The effect of aggregate size on compaction and pore space

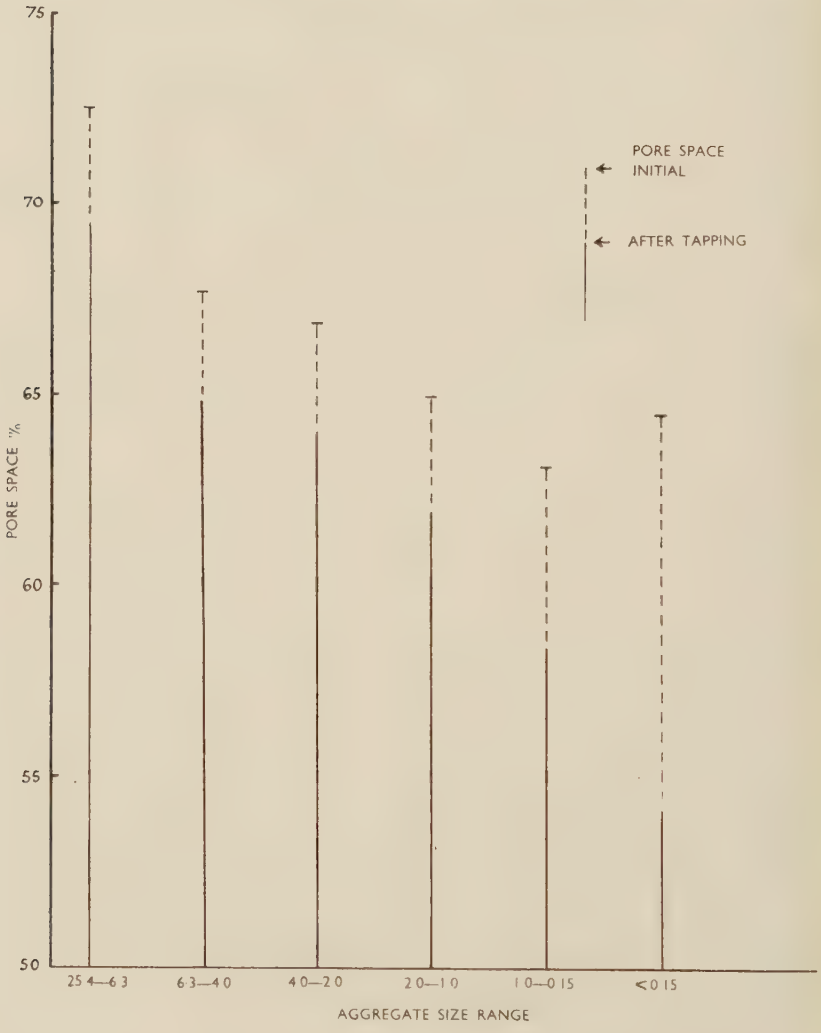
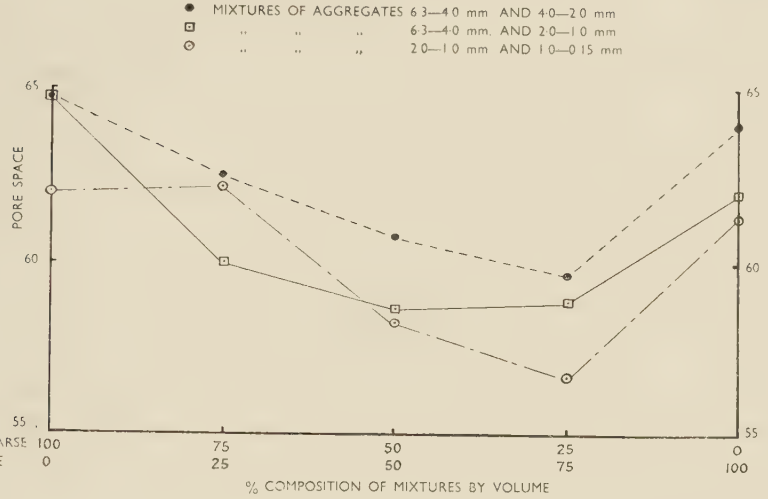


Figure 6 –Pore space of compacted mixtures of soil of different aggregate size (Yaxley clay subsoil)


MIXTURES OF AGGREGATES 6·3—4·0 mm AND 4·0—2·0 mm
" " " 6·3—4·0 mm. AND 2·0—1·0 mm
" " " 2·0—1·0 mm AND 1·0—0·15 mm
PORE SPACE
65
60
55
COARSE 100 75 50 25 0
FINE 0 25 50 75 100
% COMPOSITION OF MIXTURES BY VOLUME

Improvement of soil stability to watering

The improvement of the stability of soils was discussed in the Annual Report for 1951. Since then several " soil conditioners " have become available. Two formulations of a hydrolysed polyacrylonitrile, called in this Report Soil Conditioners 'A' and ' B ' have been used to treat Yaxley clay loam sub-soil in cropping trials with a few pots, and the effect of 'A' on stability of two soils has been examined in laboratory tests. 1,500 g. of air-dry soil was placed in a tin and the requisite amount of soil conditioner 'A' was added. The lid was replaced and the contents were well shaken. Water sufficient to wet the soil to capacity was sprayed on, and the soil was allowed to dry out. Triplicate 50 g. samples were taken for wet sieving. Two sieves were used, 2·0 mm. and 0·2 mm. The soil recovered from each sieve was transferred to a clock glass, dried at 105° C., and weighed. Allowance was made for moisture present in the original 50 g. sample by a separate moisture determination and all calculations were based on oven-dry weight.

The two samples of Yaxley soil and the two of Rhayader soil used in these tests were from different batches dug at different times. The stability of a soil can be altered by its previous treatment, particularly watering and drying cycles, and it is not surprising that there are differences between the samples of soil from the same general source, used to test the two different concentrations of conditioner in these experiments. The effects of 0·1% and 1·0% of conditioner 'A' are therefore not comparable and the results are given in separate tables. In each case the soils were sieved into small ($<\frac{1}{4}''$) and large ($>\frac{1}{4}''$) aggregates. Table 3 shows that 0·1% conditioner 'A' greatly improved the stability of the Yaxley soil of both initial aggregate sizes.

Table 3. Effect of treatment with 0·1% of soil conditioner 'A' on Aggregate Stability of two soils

0·1% Conditioner	Initial Aggregate Range	Wet Sieving		
		> 2 mm	2·0—0·2mm	<0·2 mm
		%	%	%
Yaxley Clay subsoil C.	$<\frac{1}{4}''$ treated	41·6	19·5	38·9
	$<\frac{1}{4}''$ untreated	6·1	30·1	63·8
	$\frac{1}{4}$—1″ treated	44·1	26·6	29·3
	$\frac{1}{4}$—1″ untreated	2·8	31·6	65·6
Rhayader silt loam E.	$<\frac{1}{4}''$ treated	48·3	29·2	22·5
	$<\frac{1}{4}''$ untreated	28·3	37·5	34·2
	$\frac{1}{4}$—1″ treated	77·9	14·6	7·6
	$\frac{1}{4}$—1″ untreated	78·2	15·0	6·8
		±4·0	±3·0	

This concentration also slightly improved stability of the smaller aggregates of Rhayader soil. 1% of soil conditioner 'A' improved stability of both soils. (Table 4.)

Table 4. Effect of treatment with 1% of soil conditioner 'A' on Aggregate Stability of two soils.

1·0% Conditioner	Initial Aggregate Range	Wet Sieving		
		> 2 mm	2·0—0·2mm	<0·2 mm
		%	%	%
Yaxley clay subsoil D.	$<\frac{1}{4}''$ treated	90·6	3·1	6·3
	$<\frac{1}{4}''$ untreated	5·5	36·7	57·8
	$\frac{1}{4}$—1″ treated	89·0	7·4	3·6
	$\frac{1}{4}$—1″ untreated	10·7	34·7	54·6
Rhayader silt loam F.	$<\frac{1}{4}''$ treated	97·3	0·8	1·9
	$<\frac{1}{4}''$ untreated	45·3	31·7	23·0
	$\frac{1}{4}$—1″ treated	94·8	4·5	0·7
	$\frac{1}{4}$—1″ untreated	73·2	13·7	13·1
		±2·1	±1·1	

Discussion

Experience on commercial farms suggests that casing soil which has little structure or which breaks down to form a pan when watered causes reduction in yield. Experimental support for this is given in Experiment 16 (Edwards, 1952) in which the same casing soil graded into coarse ($>\frac{1}{4}''$) and fine ($<\frac{1}{4}''$) fractions was used. The beds cased with the coarse soil yielded considerably better than those covered with fine soil. It is not yet known exactly why this should be, but the settling experiments show that the larger the aggregate size the greater the soil pore space is likely to be. Fine soils pack down more easily than the coarser ones, and uniformity of aggregate size may be more important than the proportion of large lumps. Soil conditioners may be useful in this connection for preserving structure.

The effect of soil pore space upon some of the conditions in the soil and compost has been studied. It is shown that the rate of diffusion of gases out of and into the compost via the soil is related to the soil pore space irrespective of aggregate size. Using data for carbon dioxide concentrations found in the compost before and after the soil is watered, and estimates of its production in the compost it is shown how watering the soil reduces the soil pore space and consequently decreases the rate of diffusion of carbon dioxide through the soil. Carbon dioxide accumulates until the concentration is high enough to produce a rate of diffusion which keeps pace with the production of carbon dioxide. As the soil dries out and its pore space increases, the carbon dioxide concentration in the compost decreases. Thus the carbon dioxide concentration in compost beneath a practically dry soil (pore space 50%) is about 0·2 to 0·4% and under a wet soil (pore space 10%) is about 2·0%, or where the rate of carbon dioxide production is high, may rise to 5·0%.

There is no reason why similar changes in concentration will not apply to any other gases or volatile substances produced in the compost. These same factors will also govern the rate at which oxygen can penetrate from the air into the compost.

The effects of such concentrations and changes in concentration with time upon the mushroom mycelium, fruiting, etc. are not known.

It is possible to case a bed with a soil which varies considerably in the proportion of fine and coarse lumps in such a way that some parts of the bed are covered by a greater amount of soil per square foot than others. This is because of the difference in the degree of packing which occurs between fine and coarse soils. Where the soil is fine, the pore space is lower and there is more soil than if it were coarse. When such a bed is given an even watering it will result in an uneven moisture content in the soil over the bed. A fine soil with 50% pore space requires 25% more water than the same area of coarser soil with 60% pore space to produce an equal moisture content in each. This is probably one reason for variation in yields on trays or shelves unevenly cased with fine and coarse soil. It is even more important where any form of automatic watering device is used. A similar effect is obtained where there is much variation in the depth of casing material over the bed.

REFERENCES

Bavel, C. Van (1952). Soil Sci. **73**, 91.
Buckingham, E. (1904). United States Dept. of Agric. Bur. of Soils, Bull. No. 25.
Burrows, S. (1949). A.R. Mushroom Res. Stat. 1946-48.
Edwards, R. L. (1952). A.R. Mushroom Res. Stat. 1951.
Flegg, P. B. (1953). J. Sci. Food Agric., **4**, 104.
Lambert, E. B. (1933). J. Agric. Res., **47**, 599-608.
Penman, H. L. (1940, a). J. Agric. Sci., **30**, 437.
Penman, H. L. (1940, b). J. Agric. Sci., **30**, 570.
Stoller, B. B. (1936). M.Sc. Thesis. Iowa State College.

CROPPING EXPERIMENTS ON CASING SOIL

R. L. Edwards and P. B. Flegg

In the Annual Reports for 1950 and 1951, the physical properties desirable in casing soil were discussed, and some experiments with soils, both in the laboratory and in use on mushroom beds were described. During the past year work on natural soils has continued and experiments have also been started with some artificial mixtures. The object of these latter experiments is to study the effect of a much wider range of physical properties than can be found in natural soils. Sounder knowledge of the physical properties required in a good casing soil, in a form obtainable by laboratory tests, should give a better understanding of its functions, enable many poor soils to be improved by more or less standard methods, and might lead to development of an entirely artificial mixture. For this purpose four basic materials have been used:

Yaxley clay-loam sub-soil.
sand (sharp builders').
sphagnum peat (A).
vermiculite (exfoliated).

The peat 'A' used in all the experiments described here is sphagnum peat selected for high moisture holding capacity, and because it was considered very consistent in quality. Other types of peat differ widely from this in source, texture, moisture holding capacity and pore space. Experiments are in progress with some of these to determine the effect of the differences.

Mixtures of each two of these were made up in proportions 90 : 10, 75 : 25, 50 : 50, 25 : 75, 10 : 90; over 50 such mixtures and the four materials separately have been tested in the laboratory for water holding capacity and pore space, wet and dry.

The following simplified procedure was used for rapid tests, instead of the suction method previously described. 80 ml. of the mixture was soaked thoroughly, and allowed to drain for 24 hours with precautions against loss of water by evaporation. The mixture was then weighed and dried. For calculation of pore space the specific gravity of soil, sand, vermiculite, and brick chips was assumed to be 2·65 and that of peat 1·5. The results are shown in Table 5, which also shows the approximate weight of each mixture required per square foot of bed, cased $1\frac{1}{4}''$ deep, and the maximum amount of water which this will hold.

Peat 'A' and Vermiculite both have very high water holding capacities; that of the peat is about three to four times that of Vermiculite.

The pore space of the peat used is very high when dry, but is low when it is thoroughly wet. Vermiculite, on the other hand, has pore space similar to that of peat when it is dry, but wetting it to capacity does not reduce the pore space as much as it does with peat. Mixtures of these two therefore produce a material with a very high pore space when dry and a wet pore space varying between 20 and 40%.

Mixtures of peat with sand or clay have pore space in the dry state between those of peat and the sand or clay used. The pore space of such mixtures when wet is fairly consistently low, in all proportions. Brick chips added to peat raise the pore space of the peat when wet, and slightly lower it in the dry state.

Mixtures of vermiculite with either sand or clay have similar ranges of pore space. The fairly high pore space of the vermiculite wet or dry is reduced equally by sand or clay.

From these mixtures, sixteen were selected for small scale cropping experiments in the first place. The mixtures chosen included three graded series of mixtures of two materials in three different proportions by volume,

clay—peat	.. 90 : 10, 50 : 50, 10 : 90.
sand—vermiculite	90 : 10, 50 : 50, 10 : 90.
sand—peat	.. 75 : 25, 50 : 50, 25 : 75.

and five series with a range of values of one or more of the three physical properties of special interest, water holding capacity, pore space dry, and pore space wet with the maximum water content obtained in the simplified test already described. Four pots were cased with each of the

Table 5. Water Holding and Related Properties of Possible Casing Mixtures.

Water holding by soaking 80 ml. of material, allowing to drain 24 hr., then oven drying.

Material		Water held % by wt. of dry material.	Max.water held, % by volume.	Pore space dry, % by volume.	Pore space wet, % by volume.	Wt. dry/sq. ft. (3 litres) lb.	Max.water /sq.ft. lb.
Sand/Peat							
100		21	26	50	25	10·0	1·9
90	10	22	29	51	22	8·6	1·9
75	25	31	33	59	27	7·0	2·2
50	50	78	58	69	(13)	4·8	3·8
25	75	158	62	83	21	2·6	4·0
10	90	300	(83)	86	(5)	1·8	(5·4)
	100	854	81	94	16	0·6	5·3
Clay/Peat							
100		46	41	65	25	5·9	2·7
90	10	(44)	36	70	34	5·2	2·4
75	25	61	40	75	35	4·4	2·6
50	50	100	51	80	30	3·3	3·4
25	75	216	58	88	30	1·7	3·8
10	90	315	62	90	28	1·3	4·0
	100	854	81	94	16	0·6	5·3

Material		Water held % by wt. of dry material.	Max. water held, % by volume.	Pore space dry, % by volume.	Pore space wet, % by volume.	Wt. dry/sq. ft. (3 litres) lb.	Max. water /sq. ft. lb.
Brick Chips/Peat							
100		20	16	70	54	5·2	1·1
90	10	28	18	75	58	4·2	1·2
75	25	55	30	78	49	3·5	2·0
50	50	115	52	81	(30)	2·9	3·4
25	75	259	57	89	34	1·4	3·8
10	90	527	67	93	26	0·8	4·4
	100	854	81	94	16	0·6	5·3
Verm./Peat							
100		241	51	92	41	1·7	3·5
90	10	(235)	55	91	37	1·6	3·5
75	25	338	55	93	38	1·1	3·6
50	50	463	66	93	28	1·0	4·3
25	75	774	71	94	23	(0·6)	4·6
10	90	(549)	(63)	94	(25)	0·8	(4·2)
	100	854	81	94	16	0·6	5·3
Clay/Verm.							
100		46	41	65	25	5·9	2·7
90	10	52	(44)	68	25	5·4	2·9
75	25	58	(38)	72	35	4·2	2·5
50	50	83	42	79	34	3·5	2·7
25	75	130	47	85	39	2·0	3·1
10	90	141	51	89	39	1·9	3·4
	100	241	51	91	42	1·7	3·4
Sand/Verm.							
100		21	26	50	25	10·0	1·9
90	10	27	32	54	(22)	8·3	2·1
75	25	32	35	59	24	7·1	2·2
50	50	49	42	71	30	5·4	2·7
25	75	89	47	80	34	3·4	3·1
10	90	112	51	88	35	2·9	3·4
	100	241	51	92	41	1·7	3·4
Verm. Grade	Mesh per inch						
I	18-36	182	69	86	18	2·5	4·6
II	10-18	392	63	94	31	1·0	4·1
III	6-10	302	38	96	58	0·9	2·5
V	4-6	280	34	96	63	0·8	2·2
VI	2-4	270	24	97	72	0·6	1·6

Values in brackets appear to be anomalous but have not been further investigated.

sixteen mixtures chosen and a few trays were also used; some of these mixtures fitted into more than one series. Unfortunately it was found that the pots cased with vermiculite alone or vermiculite-sand were very late coming into crop, though when they did start fruiting they gave yields within the general range of the mixtures used. The late cropping was attributed to the toxic effect of magnesium, which could be partly leached out of vermiculite by washing in water. Pots which started cropping 3—6 weeks late could not be satisfactorily compared with those starting at the normal time, and the virtual loss of these pots containing vermiculite broke up all the five series chosen to study physical properties, and one of the others. The other mixtures did not show any consistent relationship between physical properties and cropping performance, but as a result of this experience it should be possible to devise some better series for this purpose.

In the course of this experiment it became clear that more attention would have to be paid to management of the artificial casings, particularly their water content, because of their very much wider range in this respect, compared with soil. It also appeared possible that some of the mixtures used might be worth commercial trial when more was known about their management.

Table 6. Casing materials on pots

Casing No.	Mixture parts by volume				First Pinh'ds days from spawning	First Picking days from spawning	4 weeks			Final		
	C	S	P	V			Fruiting m's per pot	Yield oz. per pot	Av. size m's per lb.	Fruiting m's per pot	Yield oz. per pot	Av. size m's per lb.
1	90		10		46	51	4	2·2	29	13	5·8	36
2	50		50		41	46	2	1·1	29	8	2·9	44
3	10		90		41	47	5·5	1·7	52	13	4·1	51
4	25			75	46	52	8·5	3·0	45	21	7·2	47
5			100		41	46	6	3·1	31	16	6·3	41
7			75	25	40	44	6	2·5	38	18	7·4	39
8			50	50	45	50	4·5	1·9	38	16	6·1	42
9				100	76	83	5	2·8	28	10	5·6	29
11		90		10	70	91	4	2·5	26	9	4·0	36
12		50		50	63	70	3·5	2·2	26	8	4·1	31
13		10		90	62	70	5	3·6	22	13	6·4	32
14		75	25		50	59	5	2·2	36	12	4·2	46
15		50	50		40	44	6	2·1	46	14	5·3	42
16		25	75		40	45	5	1·4	56	13	3·5	59

Effect of initial moisture content of artificial casings

In view of the known difficulty of wetting dry peat it was considered desirable to wet mixtures containing peat before casing; the wide range of moisture content possible with these materials made experiments on the degree of wetting desirable before they come into general commercial use. Two sets of experiments were started, one using beds of 10 sq. ft. cased with a mixture of peat and sand, the other using trays of 4 sq. ft. cased with peat and vermiculite. In each case three mixtures were prepared, called wet, medium, and dry.

The three casings received the same watering treatment, being watered when the top surface of the casing started to dry out, in practice about twice weekly.

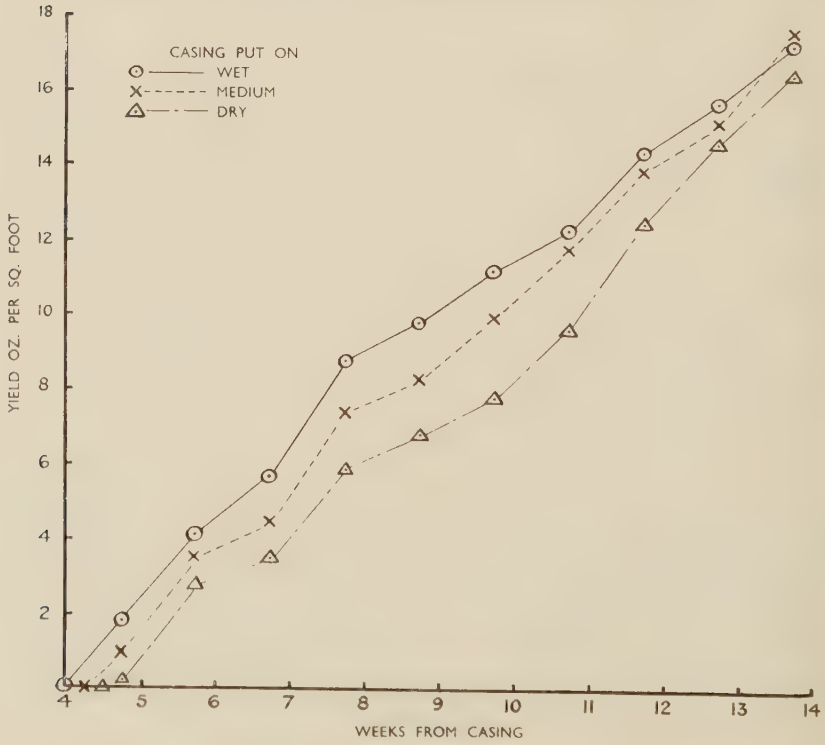
In the experiment with peat and sand, the mixture used was:

150 lb. sand
10 lb. peat
3 lb. carbonate of lime

To these quantities, 5, 2½, and 1 gallon of water was added to give the wet, medium, and dry mixtures, with 31, 15, and 6% moisture on the dry weight.

The beds were cased 26 days after spawning and the beds were watered alike, enough to keep the surface of all beds moist.

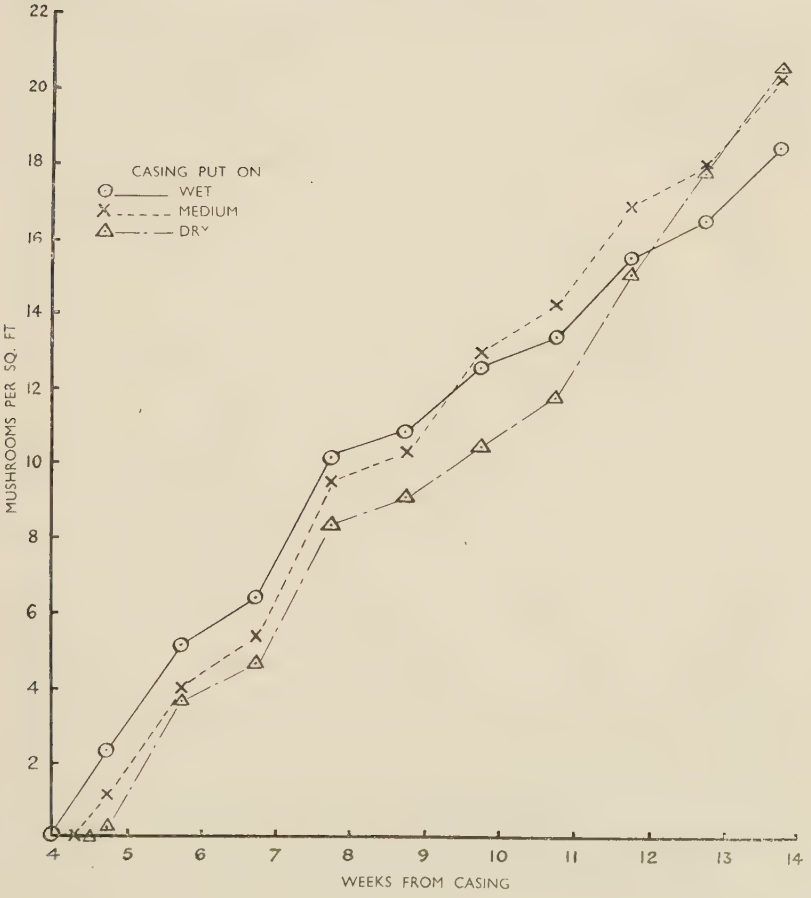
Figure 7—Yield from beds cased with peat and sand



The wet cased beds came into crop first, followed by the medium beds and then the dry ones. There was a tendency for the interval between appearance of pinheads and picking to be shorter on the wet beds. These also cropped better at first as shown in Figures 7 and 8, but after 5—7 weeks cropping the other beds began to catch up, and during the last few weeks were producing more mushrooms than the wet cased beds, which however maintained their lead in yield by weight for longer.

There are quite marked bends in the production curves of these beds, flattening out on the wet-cased beds and sloping upward on the dry cased ones, suggesting that watering satisfied the requirements of the latter and may have been excessive on the former. More detailed assessment of the results may be possible when more experiments of this kind have been carried out.

Figure 8—Fruiting on beds cased with peat and sand



In the tray experiment with peat and vermiculite, the mixture used was:—

7½ lb. peat
5 lb. vermiculite
2 lb. carbonate of lime

with 6, 5, and 2½ gallons of water giving 42, 35, and 17% of moisture on the dry weight of casing material.

In this case the wet casing came into crop first and cropped best throughout the experiment. It was followed by the medium casing, and the dry cased trays gave a much smaller number and weight of mushrooms. The results are shown in Figures 9 and 10.

It is possible that by different management, for example by heavier watering of the dry peat and vermiculite, much or all of the difference could be made up.

Grades of vermiculite

Before the apparent toxic effect of vermiculite was appreciated, an experiment was set up using pots to compare the effect of different sizes of vermiculite, in mixtures with sand, equal parts by volume. The results in Table 7 show that the two finest grades were clearly inferior, and the coarsest grade, ¼—½", gave the best results.

Two preparations of soil conditioners, one of them in two formulations for application dry and as a liquid spray, were tested on

Figure 9—Yield from trays cased with peat and vermiculite

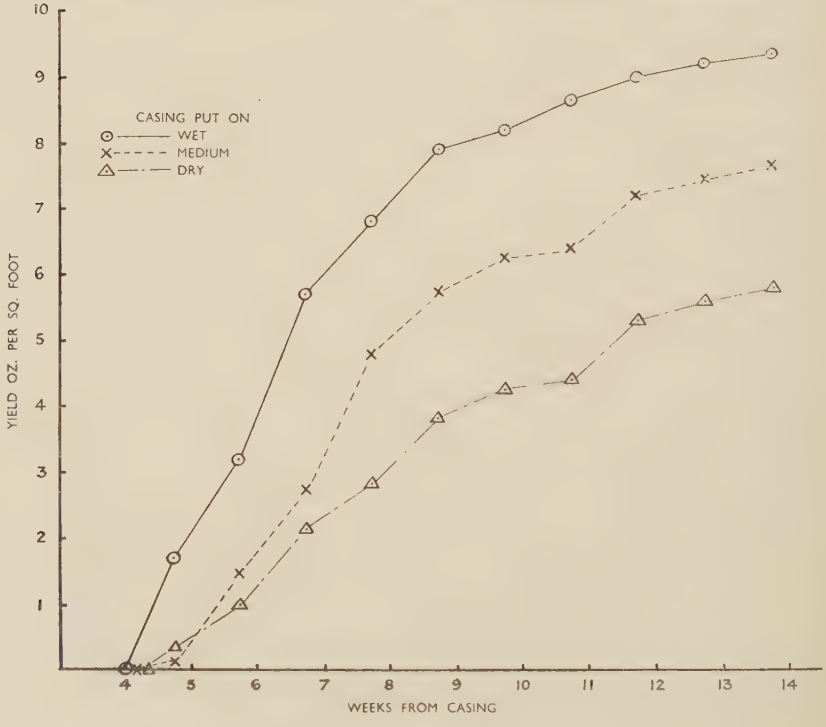


Figure 10—Fruiting on trays cased with peat and vermiculite

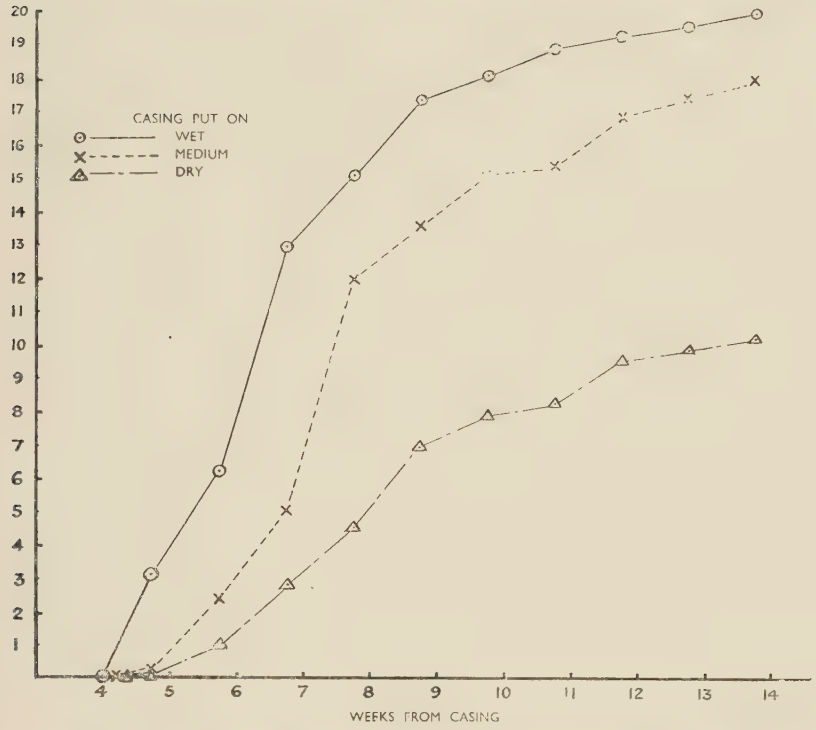


Table 7. Sand with grades of vermiculite as casing on pots
Equal parts sand and vermiculite by volume

Grade	Mesh per inch	First Pinheads days from spawning	First Picking days from spawning	Fruiting mushrooms per pot	Yield oz. per pot	Av. size mushrooms per lb.
1	18—36	120	—	none		—
2	10—18	107	120	0·5	0·2	40
3	6—10	87	99	2·2	1·9	18
4	4—6	93	101	2·0	1·8	18
5	2—4	87	98	3·0	2·6	18
MRA soil		87	102	4·1	3·1	21

two pots each. The active material in each case was a hydrolysed polyacrylonitrile. The results are shown in Table 8. With so few pots the differences in time of cropping and yield mean very little, but the effect of the soil conditioners, if any, was beneficial.

Although the Yaxley sub-soil is quite a good casing soil it does break down on repeated watering, and it was thought that the addition of small gravel ($<\frac{1}{4}''$) might confer greater stability in this respect.

Another material tested was Vermiculite, which might be expected to increase both stability to watering and moisture holding capacity. The effect of gravel was small ; Vermiculite delayed fruiting and reduced the yield. (Table 9).

Table 8. Effect of soil conditioners on casing soil

Conditioner used	First Pinheads days from spawning	First Picking days from spawning	Fruiting mushrooms per pot	Yield oz.	Av. size mushrooms per lb.
A	73	87	4·0	3·5	18
B1	81	93	3·0	3·0	16
B2	65	79	4·5	4·2	17
None	87	102	4·1	3·1	21

Table 9. Additions to clay loam casing soil

Material added	None	Gravel	Vermiculite
First pinheads ..	56	55	61 days from spawning
First picking ..	70	67	72 ,, ,, ,,
Fruiting—			
4 weeks ..	16·2	17·1	9·6 mushrooms/sq. ft.
8 weeks ..	21·0	23·8	13·9 ,,
final	21·9	24·0	14·2 ± 1·5 ,,
Yield—			
4 weeks ..	0·78	0·77	0·59 lb./sq. ft.
8 weeks ..	0·91	0·97	0·78 ,,
final	0·94	0·97	0·78 ± 0·06 ,,
Average size—			
0-4 weeks ..	20·8	25·4	16·0 mushrooms/lb.
4-8 weeks ..	35·8	34·0	22·7 ,,

One set of pots was used for an experiment on the effect of delaying the start of watering. Commercial practice varies, and watering is started at any time during 2—3 weeks after casing; most growers follow a regular routine based on experience under their own conditions. In this experiment watering was started on pairs of pots cased with dry soil 4, 8, 14 days after casing and thereafter at weekly intervals. The last pots received no water until 10 weeks after casing. Once started, watering was continued regularly each week.

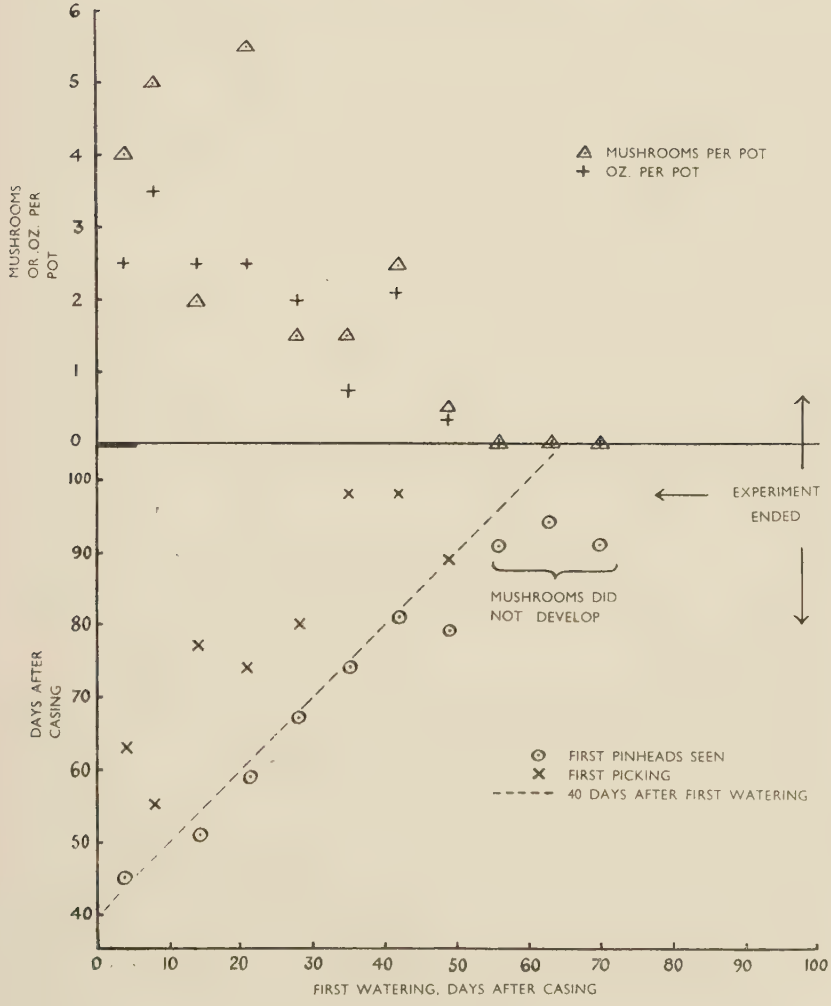
The results are in Figure 11, which also includes a broken line representing an interval of 40 days after each time of first watering.

As might be expected, fruiting was delayed in the absence of watering. It is, however, interesting to find that the interval between first watering and appearance of pinheads was so consistently just under 40 days, over a range of four weeks; and not very much different over the whole 10 weeks range of the experiment.

It is to be expected that this interval would vary according to conditions, but there may well be a fixed period of growth in moist soil, determined by the compost, type of soil and house conditions, necessary before fruiting can start.

An alternative explanation is that the limiting factor was not time as such, but the moisture content of the soil, and that this only reached a level high enough for fruiting after a certain quantity of water had been applied. With the regular watering practised in this experiment, quantity of water and time since first watering were directly related.

Figure 11—Effect of delayed watering on fruiting



GENERAL CROPPING EXPERIMENTS

R. L. Edwards

The results of cropping experiments on composts and a few on cultural practices not related to casing soil are reported under this heading.

Experiments on the use of casing soil are described in another section, with the relevant laboratory results.

In Experiment 19 there were four types of compost in a factorial design to test the effect of omitting potassium sulphate and manganese sulphate from the standard synthetic compost. Previous experiments on varying quantities of potassium sulphate have not been extended to test the effect of adding none at all, which might possibly be satisfactory if the available potassium content of the wheat straw used was adequate.

The omission of manganese was of some interest in view of the difficulty experienced at the time, in obtaining supplies of manganese salts. Six stacks were made with each of the four types of compost, following the standard formula in all other respects. Three beds were filled from each of these stacks and these were cased with three different types of soil:—

1. Yaxley clay loam sub-soil as dug.
2. The same soil screened to remove all fine soil passing through a $\frac{1}{4}''$ sieve.
3. The fine fraction of soil re-worked with a spade into larger aggregates which were then put through a 1″ screen of the type normally used.

Table 10. Effect of potash and manganese in synthetic compost

	No potash	With potash	No manganese	With manganese	
First pinheads	45·8	46·0	46·5	45·3 ± 1·1	days from spawning
First picking	55·3	55·8	54·5	56·7	,, ,, ,,
Fruiting—					
4 weeks ..	14·3	13·8	13·5	14·6	mushrooms/sq. ft.
8 weeks ..	24·6	26·5	24·6	27·8	,,
12 weeks ..	29·5	31·9	29·4	32·3 ± 1·3	,,
Yield—					
4 weeks ..	0·57	0·56	0·51	0·62	lb./sq. ft.
8 weeks ..	0·91	0·94	0·83	1·02	,,
12 weeks ..	1·04	1·12	0·98	1·19 ± 0·12	,,
Average size—					
0-4 weeks	25	25	26	23	mushrooms/lb.
4-8 weeks	30	33	35	33	,,
8-12 weeks	39	31	33	28	,,

Table 11. Effect of casing soil size and structure

	As dug under $\frac{3}{4}$"	Coarse over $\frac{1}{4}$" under $\frac{3}{4}$"	fine soil re-worked	
First pinheads	45·2	47·5	44·9 ± 0·58	days from spawning
First picking..	54·7	57·1	55·0	,, ,, ,,
Fruiting—				
4 weeks ..	15·4	13·0	13·7	mushrooms/sq. ft.
8 weeks ..	27·8	23·7	26·9	,,
12 weeks ..	32·1	27·8	32·7 ± 1·2	,,
Yield—				
4 weeks ..	0·59	0·57	0·54	lb./sq. ft.
8 weeks ..	0·96	0·92	0·90	,,
12 weeks ..	1·09	1·07	1·08	,,
Average size—				
0-4 weeks ..	26	23	25	mushrooms/lb.
4-8 weeks ..	34	30	37	,,
8-12 weeks ..	31	29	32	,,

Results:

The results from the four types of compost are given in Table 10 and those from the three casing soils in Table 11.

The omission of potassium had no significant effect on the start of cropping, fruiting or yield. The effect of manganese was slightly greater and was probably just significant. In both cases this result must depend on the quantity of potassium or manganese naturally present in the other materials, particularly the straw used in making the compost.

The casing soil experiment was not quite a repetition of Experiment 16 in which coarse, fine and mixed soils were tested. On that occasion there were other possible differences owing to the method of liming the soil and these were eliminated in the present case. In this experiment the coarse soil was slightly later coming into crop and gave fewer mushrooms than either the natural soil or the re-worked soil, though the yield in weight was the same. This often happens when the number of mushrooms is altered owing to non-nutritional causes. Further experiments on size and structure of casing soil are obviously needed.

In Experiment 20, four types of compost were made in a factorial design to test the effect of omitting the usual trace elements and to compare cut with uncut straw. The cut straw was put through a Robust chopper before stacking, whereas the uncut straw was stacked in its natural state; both groups of composts were thereafter turned by hand in the usual way. After eight weeks cropping the beds in this experiment were used to test the effect of sprays supplying nitrogen, phosphorus, and trace elements, and also salt which is used as a stimulant spray by

many growers during the crop. The following sprays were used:—

F 10% solution of salt, 200 ml. on 10 sq. ft. (1 lb. in 1 gallon on 225 sq. ft.).
G 10% solution of urea, 200 ml. on 10 sq. ft.
K 10% suspension of superphosphate, 200 ml. on 10 sq. ft.
L trace element mixture, suspension equivalent to 20 g. mixed salts on 10 sq. ft.

The salt and urea caused the caps of the mushrooms on the beds at the time of spraying to turn brown within two hours. All the beds were watered within a few hours after spraying to dilute the sprays and wash them into the casing soil.

Results:

There was no difference in cropping due to cutting the straw or omitting the trace elements (Table 12). All the yields were low and would not be expected to make severe demands on the quantities of trace elements naturally present in the straw and dried blood, so that this part of the experiment was ineffective. The experiment ended less than three weeks after applying the sprays. During this time the beds treated with salt gave a slightly higher yield, which might be significant. Those treated with urea gave a slightly, but not significantly lower yield. Superphosphate and trace elements had no effect. (Table 13.)

Table 12. Effect of cutting straw and trace elements

	Straw		Trace elements		
	cut	uncut	omitted	included	
First pinheads	58	60	58	59	days from spawning
First picking ..	65	66	65	65	„ „ „
Fruiting—					
4 weeks ..	6·0	6·1	5·9	5·8	„ „ „
8 weeks ..	10·5	9·8	10·1	10·2	mushrooms/sq. ft.
Yield—					
4 weeks ..	0·41	0·38	0·40	0·39	lb./sq. ft.
8 weeks ..	0·66	0·61	0·63	0·64	„
Average size—					
0-4 weeks ..	15	16	15	15	mushrooms/lb.
4-8 weeks ..	18	16	18	18	„

Table 13. Effect of spray treatments on beds during cropping
(in 18 days after treatment)

Spray treatment	mushrooms/ sq. ft.		yield oz./ sq. ft.	average size mushrooms/lb.
Water	2·55	±0·5	2·27	18
Salt	3·5		2·63	20
Urea	1·84		1·91	15
Water	3·02		2·59	19
Superphosphate ..	2·83		2·73	17
Trace elements	3·01		2·79	17

In Experiment 21, five blocks, each of four stacks of synthetic compost, were made in a 2 × 2 factorial design. The four treatments were:—

normal potassium sulphate, normal weekly turns.
normal potassium sulphate, one extra turn.
no potassium sulphate, normal weekly turns.
no potassium sulphate, one extra turn.

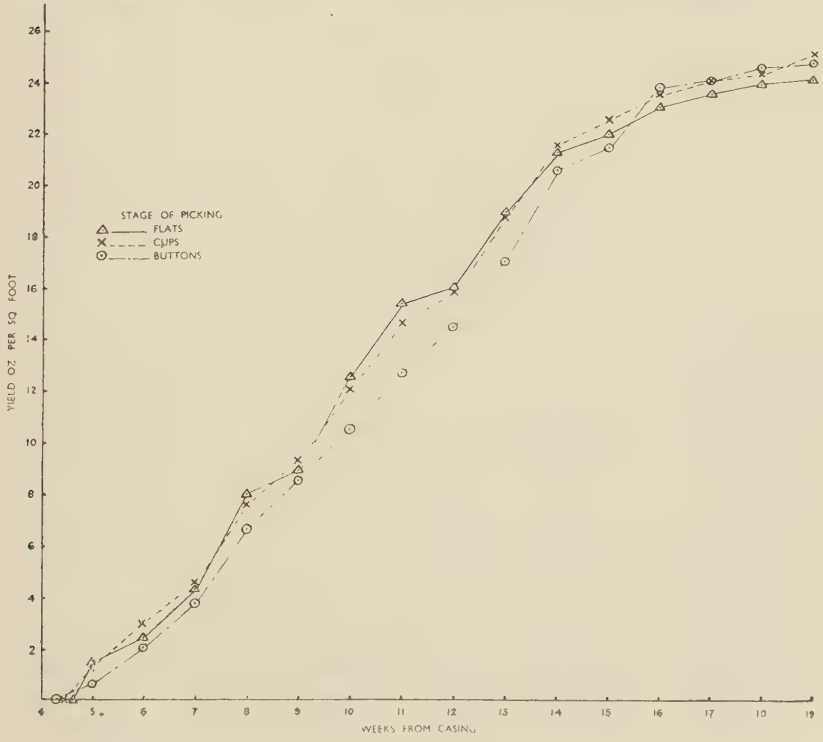
The extra turn was given in the middle of the fourth (last) week of composting. It has been suggested that in commercial practice short intervals between the last turns give the best yields.

Each stack filled three beds. These beds were subjected to further treatments at the cropping stage. Three groups of 12 beds each received their first watering 17, 24, and 30 days after casing respectively. They were cased 16 days after spawning.

On two more groups of 8 beds each, mushrooms were picked:—
while tightly closed.
approximately when the veil was breaking.
open flat.

The results are shown in Figure 12 and Table 14.

Figure 12—Effect of stage of growth at picking on yield



The yield of " buttons " was a little lower for the first 8 weeks, but then they began to catch up as production of " cups " and " flats " fell off, and after 12 weeks there was no significant difference between the three groups of beds. It is interesting to note that the three groups showed pinheads at the same time, but the greater interval needed for opening of the veil and further development to flats is reflected in the later dates of first picking of " cups " and " flats ".

Table 14. Effect of stage of picking

	Buttons	Cups	Flats	
First pinheads	40	40	40	days from spawning
First picking	46	47	48	„ „ „
Fruiting—				
4 weeks	6·1	6·6	7·2	mushrooms/sq. ft.
8 weeks	14·1	16·4	16·5	„
12 weeks	26·4	25·0	26·1	„
Yield—				
4 weeks	0·41	0·50	0·60	lb./sq. ft.
8 weeks	0·91	1·03	1·09	„
12 weeks	1·42	1·42	1·48	„
Average size—				
0-4 weeks	15	13	12	mushrooms/lb.
4-8 weeks	16	18	19	„
8-12 weeks	24	22	25	„

Table 15. Composts. Effect of potash and an extra turn

	No potash	With potash	Normal turns	Extra turn	
First pinheads ..	40	41	40	41	days from spawning
First picking ..	47	49	48	48	„ „ „
Fruiting—					
4 weeks ..	6·6	6·2	6·3	6·5	mushrooms/sq. ft.
8 weeks ..	15·4	13·1	14·0	14·5	„
12 weeks ..	24·1	22·4	23·7	22·8	„
Yield—					
4 weeks ..	0·47	0·44	0·46	0·45	lb./sq. ft.
8 weeks ..	0·94	0·92	0·94	0·92	„
12 weeks ..	1·31	1·27	1·29	1·29	„
Average size—					
0-4 weeks ..	14	14	14	14	mushrooms/lb.
4-8 weeks ..	19	14	16	17	„
8-12 weeks ..	23	27	28	22	„

As in Experiment 19, the omission of potassium from the compost had no effect on yield; there was no difference due to the extra turn. (Table 15.)

When watering was delayed for as long as 30 days after casing the start of fruiting and development of the mushrooms were delayed, as shown in Table 16, but the final yield was not adversely affected, and was slightly but not significantly greater than that from beds first watered 17 days after casing.

Table 16. Time of first watering

Days from casing	17	24	30	
First pinheads ..	40	41	42	days from spawning
First picking ..	47	48	51	,, ,, ,,
Fruiting—				
4 weeks	8·2	8·6	8·2	mushrooms/sq. ft.
8 weeks	18·8	18·8	20·6	,,
12 weeks	27·2	30·1	30·5	,,
Yield—				
4 weeks	0·57	0·57	0·54	lb./sq. ft.
8 weeks	1·17	1·14	1·23	,,
12 weeks	1·55	1·61	1·70	,,
Average size—				
0-4 weeks	14	15	15	mushrooms/lb.
4-8 weeks	18	18	18	,,
8-12 weeks ..	22	24	21	,,

In Experiment 22, sixteen stacks of synthetic compost with urea were made in the usual small bays. Eight of these stacks were turned by a machine fitted with three sets of rotating flat blades, which break up lumps of compost very thoroughly without cutting the individual straws much. The other eight stacks were turned by hand, little attempt being made to break up the lumps of compost. The object was not to compare the machine with good hand turning, but to assess the importance of thorough shaking at each turn, which was done consistently by the machine, but not by hand turning as it was done deliberately in this experiment. All the stacks were turned weekly for four weeks, and the top, middle, and bottom parts of each stack were interchanged as usual. Each stack filled three beds of 10 sq. ft.

In addition to these sixteen stacks, four others were made as a preliminary trial of the short composting process, applied to synthetic compost with urea as source of nitrogen. Two of these were made in our usual rectangular shape, about 4′ 6″ wide and 5′ high at the start, the other two were made triangular in section, 4′ 6″ wide and 4′ 6″ high, and of course about twice as long to accommodate the same amount of compost. One stack of each shape was composted for 8 days, with turns on the third and fifth days, and the other stacks were composted for 13 days, with turns on the fifth, seventh, and tenth days. The straw

had been wetted in Noble Mushrooms' spraying house which wets it more throughly than is always possible with a drip-pipe out of doors. All the four stacks heated, as shown in Table 17, but they looked very much under-composted, light coloured, long, and tough, when the beds were made. This was done at the pre-arranged time, and was not based on the state of the compost. All the straw used for this experiment was chopped twice, at the beginning and end of composting.

The yields from the four short composts are given in Table 18, with the average yield of the standard composts most like them in casing and other respects. As these were not made in the same replicated block they cannot be compared by the usual analysis of variance. The yields from the short composts were all lower than those from normal stacks; 13 day composts were better than the shorter ones, and rectangular stacks were better than triangular ones. In view of the small scale of the experiment these must only be regarded as general indications, but it may be noted that in 1949 a satisfactory yield was obtained from synthetic compost made in 3 weeks with weekly turns.

Table 17. Maximum temperatures observed in stacks of " short " compost (about 1 ft. below top of stacks)

	Triangular		Rectangular	
	8	13	8	13 days
After stacking	24	43	30	42 °C.
After 1st turn	30	40	39	45
2nd turn	42	40	48	47
3rd turn		45		52

Table 18. Short composts, with MRA activators

	Standard MRA compost (28 days)	Rectangular 8 days	Rectangular 13 days	Triangular 8 days	Triangular 13 days	
First pinheads ..	58	55	53	59	56	days from spawning
First picking ..	72	67	65	72	69	,,
Fruiting—						
4 weeks ..	16·2	13·0	16·7	8·7	11·7	mushrooms/sq. ft.
8 weeks ..	22·5	18·0	21·0	11·3	16·0	,,
Yield—						
4 weeks ..	0·86	0·58	0·71	0·38	0·60	lb./sq. ft.
8 weeks ..	1·08	0·75	0·85	0·46	0·71	,,
Average size—						
0-4 weeks ..	18·7	22·3	23·5	23·1	19·3	mushrooms/lb.
4-8 weeks ..	29·0	30·0	29·7	32·0	41·6	,,

The results of the comparison between hand and machine turning are given in Table 19. They show a small difference in favour of machine turning, suggesting that the thorough aeration of the compost which this method ensures does improve it. It is not suggested that *thorough* shaking by hand during turning is inferior.

Table 19. A comparison of hand and machine turning

	Hand	Machine	
First pinheads	52	53	days from spawning
First picking	66	65	,, ,, ,,
Fruiting—			
4 weeks	11·1	13·1	mushrooms/sq. ft.
8 weeks	17·6	20·4	,,
final	18·9	22·2±4	,,
Yield—			
4 weeks	0·59	0·70	lb./sq. ft.
8 weeks	0·90	1·09	,,
final	0·97	1·20±0·091	,,
Average size—			
0-4 weeks	18·9	18·7	mushrooms/lb.
4-8 weeks	20·6	18·9	,,

MICROBIOLOGY DEPARTMENT

Miss D. G. Gandy

The past year has seen the completion of the Disease Room, thus providing facilities for experiments on mushroom diseases and pests on a scale not previously possible at Yaxley. Results of the first experiments carried out have not been as satisfactory as hoped, but valuable experience has been gained in the practical aspects of setting up this type of experiment.

Advisory work

During 1951, over a hundred samples were received from growers and examined. The following is a list of the more important fungi, insects and other pests isolated from them together with the number of times each was found.

Parasitic on Mushrooms

Dactylium dendroides	3
Mycogone perniciosa	4
Verticillium malthousei	1

Competitors or Invaders

Papulaspora byssina	4
" Verdigris "	4
Scopulariopsis fimicola	3
Chaetomium sp.	2
Pseudobalsamia microspora	2
Oedocephalum fimetarium	1
Trichoderma viride	1
Botrytis gemella	1
Botrytis sp.	1
Bacterial Pit	1
Clitopilus cretatus	1
" Mummy Disease "	1

Pests

Nematodes	32
Cecid larvae	11
Mites	12
Springtails	4
Phorid larvae	3
Sciarid larvae	2

Experimental Work

Nematode infestation was by far the most frequent cause of trouble in those samples sent for examination. The elimination of eelworms once an attack has developed presents certain difficulties since they spread throughout the compost. Any liquid nematocide would have to be used in sufficient quantities to soak into the compost. From a cultural point of view this is most undesirable. A vapour does not have this objection,

but here the difficulty lies in ensuring that it diffuses through the beds or trays. Clearly the elimination of this pest must still be achieved by careful sterilization of all woodwork and implements which may have become infected.

Experiments were carried out to test the relative efficiency of various substances as nematocides. It was found that while many substances killed the majority of eelworms, there were always a few individuals which seemed to be very much more resistant. Owing to the rapidity with which they multiply, it is most important that any substance used for sterilization should kill *all* eelworms. The results of these experiments are summarised below :—

Substance and concentration used	Duration of treatment	Reactions observed
Phenothiazine compound.		
2%	48 minutes	Most dead, convulsive movements in the rest.
0·1%	42 minutes	Most dead, convulsive movements in the rest.
Formaldehyde		
4%	30 minutes	Dead
0·8%	30 minutes	Slight sluggish movement
	1 hr. 20 mins.	Dead
Hydroxyquinoline sulphate.		
10%	3 hrs. 30 mins.	Dead
1%	3 hrs. 30 mins.	A few still alive (1—5%)
Mixed xylenols		
10%	10 minutes	Dead
5%	22 minutes	Dead
0·5%	4 hours	A few still alive
Phenyl mercury fixtan		
2%	50 minutes	No effect
	1 hr. 3 mins.	No effect
BHC		
2%	2 hrs. 15 mins.	No effect
Toxaphene (50%)		
1·0%	1 hr. 10 mins.	Convulsive movements
Mercuric chloride		
0·5%	40 minutes	Dead

Substance and concentration used	Duration of treatment	Reactions observed
Sodium chloride		
5%	2 minutes	Dead
2·5%	1 hr. 22 mins.	Many still alive
Ethylene dibromide		
0·5%	23 minutes	Dead
0·25%	20 minutes	A few still alive
	5 hrs. 15 mins.	A few still alive
Carbon tetrachloride		
5%	47 minutes	Dead
Dichloropropylene and Dichloropropane		
10%	2 minutes	Dead
0·1%	1 hr. 30 mins.	Still alive
Phenol		
2%	10 minutes	Dead
Chlorophenol preparation		
0·25%	1 minute	Dead

Eelworms were killed at 50-55° C. Beakers of eelworm infested compost were heated in an oven at 131° F. (55° C) for 24 hours. On examination the eelworms were found to be dead, thus showing that an efficient peak heat will kill them.

The Effect of Ultra-Violet Radiation

The bactericidal effect of ultra-violet radiation is well-known and is utilised in the sterilisation of the air in offices, meat stores, etc. It is also known to effect adversely the growth of a number of fungi. Experiments were therefore carried out to find out whether ultra-violet radiation is of any practical use to mushroom growers in eliminating bacterial diseases.

The source of radiation was a 2 ft. low pressure mercury discharge tube, the radiation being mainly at the wave length of 2537 A.U., suspended 2 ft. above the trays. Some trays from another experiment in which Bacterial Pit had occurred were used.

When the pitting began to appear, the half of each box which was to receive indirect radiation was covered with thick paper. The boxes then received a total of nine hours of radiation, given in three doses. On the first day they received 1½ hours. This caused the caps of the exposed mushrooms to turn a very pale golden colour. This colouration deepened

and spread with succeeding doses, and was accompanied by slight shrivelling of the caps. The veils of such mushrooms appeared to break prematurely and the gills were of a redder colour than normal. *All young pinheads were shrivelled and dead.* The pits on the older mushrooms were dried up. The mushrooms which did not receive direct irradiation appeared to be unaffected. They were normal in colour and texture and the pitting continued to spread. Pinheads were normal.

To sum up, while ultra-violet radiation appeared to check the spread of ' Bacterial Pit ' and caused the pits which had developed to dry up, it was also injurious to mushrooms, especially pinheads. The effect of irradiation of beds between flushes is not known.

Experiments on Truffle (*Pseudobalsamia microspora*)

Experiments were continued on the same lines as previously reported. So far copper sulphate remains the most promising fungicide for the control of this competitor, but results of experiments carried out both in the laboratory and on mushroom farms have varied considerably, very good results having been obtained in some cases while failure was recorded in others.

In the laboratory, an experiment was carried out using the following substances :—

Salicylic acid	.. 2%
Thiram I preparation	2%
Thiram I preparation	1%
Thiram II ..	.. 2%
Thiram II ..	.. 1%
Copper sulphate	.. 2%
Copper sulphate	.. 1%

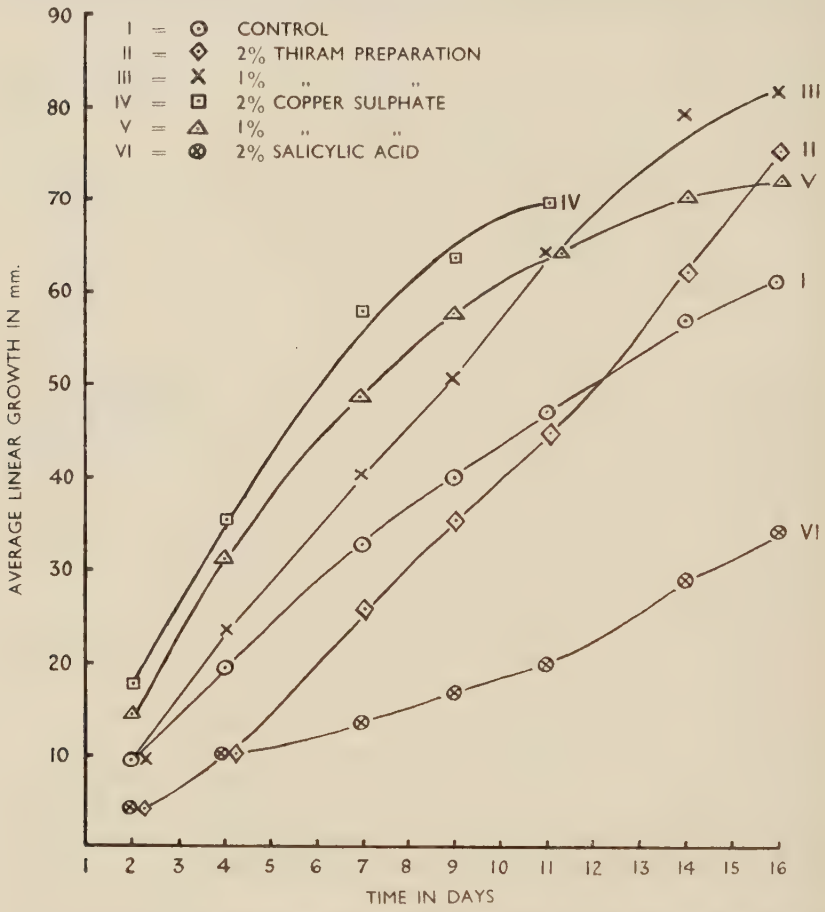
These concentrations were based upon the wet weight of a compost, having a moisture content of 80%. The original moisture content was 75% and the substances being tested were dissolved in sufficient water to raise it to the required level.

The compost was then packed into boiling tubes, peak heated in an electric oven, spawned and incubated at 25° C. Ten tubes of compost were allotted for each fungicide test. Control compost was treated with water only. The tubes were inoculated with truffle ascocarps when the mushroom mycelium had begun to grow.

No growth of mushroom took place in compost treated with Thiram II. Growth was less with 2% Thiram I than with 1%, and there appeared to be an inhibitory effect at this high concentration. Growth in the other tubes was satisfactory.

The results of this experiment were striking. All the tubes became heavily infected with truffle except those treated with copper sulphate which remained entirely free of the disease. Growth curve of mycelium is shown in Figure 13.

Figure 13—Growth curve of mushroom mycelium through treated compost



In view of the encouraging results obtained in the above experiment, a further series of trials was set up using copper sulphate in the following concentrations (ten tubes each) :—

2% of the dry weight of the compost
1% " " " " " " "
0·5% " " " " " " "
2% of the wet weight of the compost
1% " " " " " " "
0·5% " " " " " " "

The lower concentrations were introduced since it was felt that 2% was rather high for application on a commercial scale and might have an inhibitory effect on the growth of mushrooms.

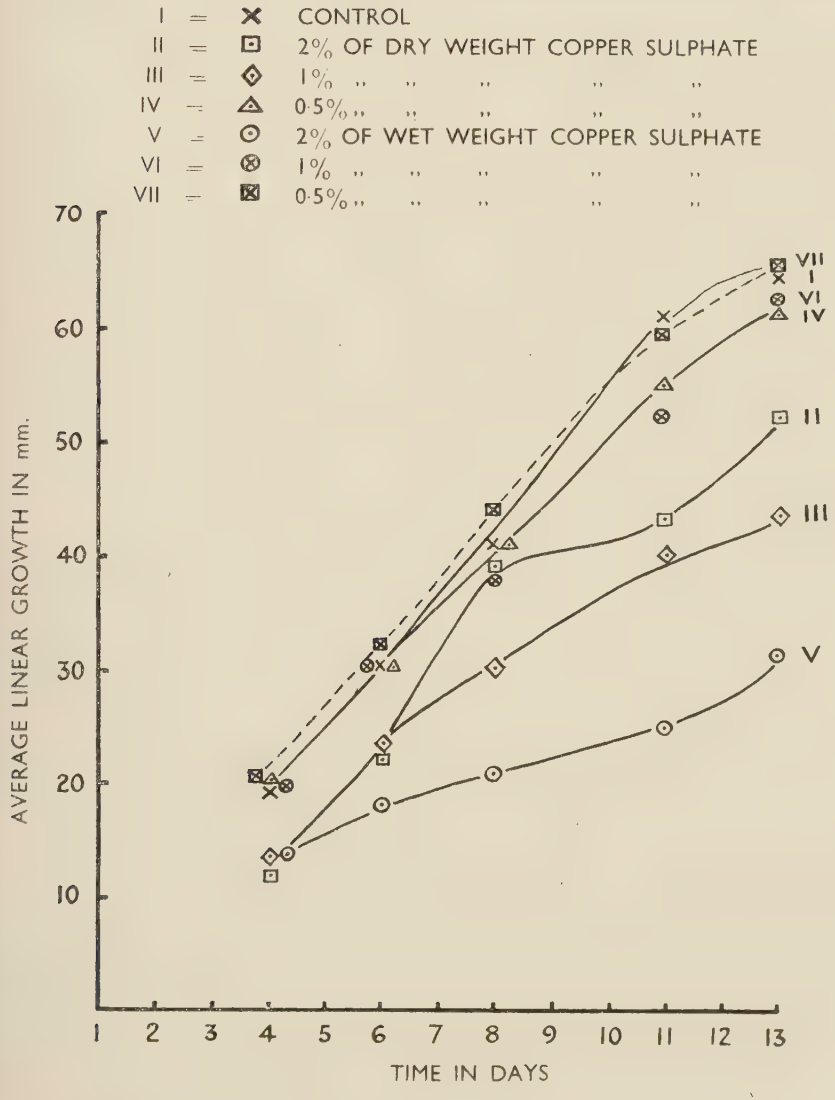
The compost had an original moisture content of 66·5% and this was brought up to 80% for the experiment.

The results obtained demonstrate the erratic behaviour of truffle. It developed in the following :—

2 tubes Control
2 tubes 1% copper sulphate of dry weight of compost
1 tube 0·5% „ „ „ „ „ „ „

Mushroom mycelium failed to grow in 3 tubes treated with 2% (of dry weight) copper sulphate. Truffle failed to develop in compost

Figure 14—Growth curve of mushroom mycelium through treated compost



receiving the higher concentrations of copper sulphate, but the low rate of infection in the controls indicate that the environmental conditions may not have been favourable to its development, irrespective of the fungicide treatment. Growth curve is shown in Figure 14.

Red Geotrichum (*Sporendonema* sp.)

Trays having casing soil infected with this fungus were given the following spray treatments :—

Phenyl mercury fixtan ..	0·1%
Zineb	1·0%
Thiram	3·0%

The trays were sprayed at the rate of half a pint per square foot.

Results:

1. Phenyl mercury fixtan.

   The areas of bed sprayed with this produced no further mushrooms. Geotrichum was checked.

2. Zineb.

   Geotrichum was checked. Treated areas produced mushrooms.

3. Thiram.

   Geotrichum was not checked.

The results from spraying with zineb were in accord with those obtained from spraying trials in 1950 where both zineb and thiram were tried.

It is hoped to carry out further trials of this type when the opportunity occurs.

Experiments on the control of Mycogone and Verticillium

Two further trials of zineb and thiram were carried out against *Mycogone* and *Verticillium*. These constituted the first experiments carried out in the disease room and were not very successful owing to lack of experience with experiments of this kind. Many of the trays used failed to produce any mushrooms. The trays were inoculated by spraying the casing soil with a suspension of spores. The treatments then given were as follows:—

First experiment:—Control—70 ml. of water sprayed on to each tray.
Zineb—70 ml. of 0·1% solution per tray.
Thiram—70 ml. of 0·3% solution per tray.

Six weeks after inoculation it was found that *Verticillium* was the only disease to have developed. Accordingly all boxes were inoculated again. After this both *Verticillium* and *Mycogone* were found on the mushrooms, but in neither this nor the next experiment was an attack by *Dactylium* established. It is therefore clear that environmental conditions play an important part in determining the incidence of attack by these diseases even when a heavy infection is present. The avoidance of conditions which favour the growth of these fungi is therefore important especially when a grower believes that his casing soil is infected yet does

not sterilize it. High relative humidity and temperatures are generally most favourable to spore germination, and in this experiment it was not possible to provide these conditions. The average temperature was 15° C. (59° F.) and average relative humidity was 58%.

The number and weight of mushrooms picked in this experiment were as follows :—

Treatment	*Mycogone*				*Verticillium*			
	Healthy		Diseased		Healthy		Diseased	
	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.
Zineb ..	5	9	2	3	28	21	10	14
Thiram ..	14	15	2	6	7	9	7	5
Control ..	11	11	20	15	2	2	22	17

In the second experiment the treatments given were as follows:—

Zineb 7 g. per cwt. of soil added to the soil at casing.

Thiram 7 g. per cwt. of soil added to the soil at casing.

No further difficulty was encountered in establishing attack by *Mycogone* and *Verticillium*. The average temperature was 20° C. (68° F.) and relative humidity 88%.

The number and weight of mushrooms obtained from this second experiment are recorded in the table below.

Treatment	*Mycogone*				*Verticillium*			
	Healthy		Diseased		Healthy		Diseased	
	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.	No.	Wt. oz.
Zineb ..	43	66	32	30	30	37	19	34
Thiram ..	20	29	35	26	12	21	11	17
Control ..	41	45	62	54	31	38	27	40

The measure of control obtained in this experiment was not very effective due probably to the small quantities of fungicide used. Since it was mixed with the soil, only a small proportion remained on the surface where it would be most effective.

Verdigris and Mat disease

An investigation has been started on these diseases. It is clear that several yellowish green fungi are associated with the condition described under these names. So far three have been isolated, one has been identified as *Myceliophthora sulphurea*, while another is believed to be a variety of *M. lutea*. Evidence as to the damage caused by these diseases is conflicting, due probably to the fact that different fungi may be involved. It has also been suggested that these fungi are not in themselves harmful but may indicate unfavourable conditions in the mushroom compost.

The effect of magnesium on the growth of mushroom mycelium

It is known that excess of magnesium has a detrimental effect on mushroom production (Anon., 1949 ; Edwards). It is present in gypsum and vermiculite which is being used as a casing material. For this reason experiments were started to obtain more information on the effect of magnesium on mycelial growth. Normally the concentration of magnesium in gypsum falls below the concentrations believed to be injurious, but one case has been recorded where a sample of gypsum contained 17% of magnesium. The final concentration of magnesium in compost treated with this gypsum would be about 0·3% by weight.

In the two experiments carried out to date the mycelium was grown on 2% malt agar containing the following magnesium concentrations:—

2%, 1%, 0·12%, 0·024%, 0·0024%

Figure 15, shows the average daily increase in area of the mushroom colonies in sq. in. These results were obtained from experiments carried out at different times, C I being the control to 0·12, 0·024, and 0·0024% Mg. while C II was the control to 2% and 1% Mg. Bearing this in mind, it will be seen that concentrations of less than 0·12% may increase the rate of growth while those over 1% have a detrimental effect on growth. Treschow found that the dry matter production in liquid media was increased with concentrations of magnesium sulphate up to 0·025 molar providing that calcium chloride and potassium chloride were also available. Results from cropping experiments show that pure vermiculite used as casing generally gave poorer crops and the magnesium concentration found in the vermiculite is one probable cause of this.

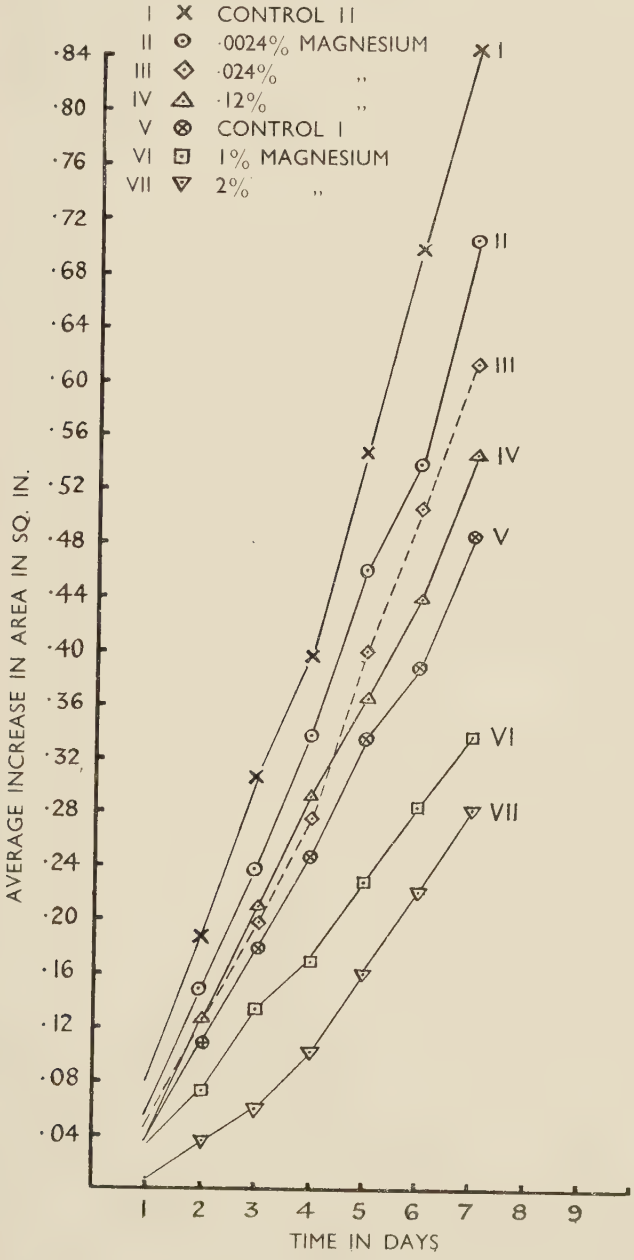
REFERENCE

Treschow, C. (1941), Dansk Bot. Ark., **11**, 1.

Anon. (1949). 62nd A. R. Penn. Agric. Exp. Sta. (abstract only).

Edwards, R. L., unpublished observations.

Fig. 15—The effect of magnesium on the growth of mushroom mycelium



LIST OF PUBLICATIONS

S. Burrows:

Technical control in mushroom growing, 1947, MGA Bull. No. 9.

Aerobic medium for fungus growth studies. 1949, Nature, **164**, 30.

Colloids: what are they? 1949, MGA Bull. No. 16.

Water and mushrooms, 1949, MGA Bull. No. 17.

A colorimetric method for the determination of oxalate, 1950, Analyst, **75**, 80.

Water changes in mushroom beds, 1950, MGA Bull. No. 18.

Method of Sampling and Analysis of Mushroom Compost and the Determination of Absolute Changes in them. 1950, Mushroom Science **1**, MGA, Yaxley, Peterborough.

Some Chemical Changes in Mushroom Composts. 1950, Mushroom Science **1**, MGA, Yaxley, Peterborough.

The Chemistry of mushroom composts.

I. General introduction and methods of investigation. 1951, J. Sci. Food. Agric., **9**, 395.

II. Nitrogen changes during the composting and cropping processes. 1951, J. Sci. Food. Agric. 9, 403.

C. Duncan:

How to pack specimens, 1949, MGA Bull. No. 16.

R. L. Edwards:

Food value of the mushroom, 1946, MGA Year Book.

The Mushroom Research Association, 1946, MGA Bull. No. 4.

Insulation of mushroom houses, 1947, MGA Bull. No. 6.

Statistical analysis, 1947, MGA Bull. No. 7.

Mushroom research (Talk to Worthing Growers), 1948, MGA Bull. No. 11.

MRA Report on synthetic compost, 1949, MGA Bull. No. 15.

Mushroom casing soils, 1949, MGA Bull. No. 16.

Developing a synthetic compost, I, 1949, MGA Bull. No. 16.

Science in the mushroom industry, 1949, Agriculture, **56**, 434.

Developing a synthetic compost, II, 1950, MGA Bull. No. 18.

Mushroom growing in Denmark, 1950, MGA Bull. No. 18.

On the insulation of mushroom houses, 1950, MGA Bull. No. 18.

A visit to Holland and Belgium, 1950, MGA Bull. No. 19.

First International Conference on Mushroom Science, 1950, MGA Bull. No. 20.

Developing a synthetic compost III, 1950, MGA Bull. No. 21.

Factors affecting comparisons between yields, 1950, Mushroom Science **1**. MGA, Yaxley, Peterborough.

Some factors affecting fructification in the mushroom, 1950, Mushroom Science **1**. MGA, Yaxley, Peterborough.

A design for mushroom cropping experiments, 1950, Mushroom Science **1**. MGA, Yaxley, Peterborough.

Synthetic compost, 1950, Mushroom Science **1**. MGA, Yaxley, Peterborough.

The work of the Mushroom Research Association, 1951, Scientific Horticulture, **10**, 144.

R. L. Edwards:

How to avoid trouble. 1951, MGA Bull. No. 24.

Notes from advisory work. 1952, MGA Bull. No. 26.

Cost and profits. 1952, MGA Bull. No. 30.

Research in Western Europe. 1952, MGA Bull. No. 33.

R. L. Edwards & P. B. Flegg:

Some artificial mixtures used in casing soil experiments. 1953, MGA Bull. 42.

R. L. Edwards & C. J. La Touche:

Hygiene on the mushroom farm, 1948, MGA Bull. No. 11.

I. F. Storey & R. L. Edwards:

Ventilation and the growth of mushrooms. 1951, MGA Bull. No. 25.

P. B. Flegg:

How much lime? 1951, MGA Bull. No. 25.

Manurial value of spent mushroom compost, 1952, Grower, **37**, 149 and 379.

Science and the grower. 1952, MGA Bull. No. 31.

Spent compost as a manure. 1953, MGA Bull. No. 38.

Effect of aggregation on the diffusion of gases and vapours soils. 1953, J. Sci. Food. Agric., **4**, 104.

C. J. La Touche:

Passive movements of spores in *Verticillium*, etc., 1947, Nature, **160**, 679.

Brown Plaster Mould, 1947, MGA Bull. No. 8.

Mushroom abnormality, 1948, MGA Bull. No. 12.

Toadstools versus mushrooms, 1948, MGA Bull. No. 14.

Spore prints from individual phialides of *Verticillium* spp. 1949, Nature, **163**, 69.

Slide traps for soil fungi, 1948, Trans. Brit. mycol. Soc. **31**, 281.

Chaetomium-like thermophile fungus, 1948, Nature, **161**, 320.

New thermophile species of *Chaetomium*, 1949, Trans. Brit. Mycol. Soc., **33**, 94.

Some French mushroom farms, 1949, MGA Bull. No. 17.

Mushroom Research Station Reports, 1946-48.
1949.
1950.
1951.

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Preparation of MRA Synthetic Compost

Supplement to the Annual Reports of the Mushroom Research Station for 1949, 1951, and 1952

There have been some minor developments in the method of handling this synthetic compost since 1949. Activators are now available ready mixed and for this purpose the manufacturers put Activator B in with the other main ingredients, the Activators being renamed Activator 1, to be added to the wet straw when the stack is made, and Activator 2, to be added at the last turn, or when the compost is shaken out for filling. The quantities of ready mixed Activators are 4 cwt. of Activator 1, and 84 lb. of Activator 2 per ton of wheat straw (dry weight).

Growers mixing their own Activators for storage should split up the constituents of Activator B, putting potassium bromide and potassium iodide in with the superphosphate and gypsum of Activator C. If the Activator is to be used immediately this need not be done. The small quantities, less than a pound per ton of wheat straw, should in any case be mixed together first and if they are to be added in dry form, they should be finely powdered and mixed with a few pounds of gypsum before adding them to the main bulk. Alternatively they can be mixed with water and sprinkled on the stack as directed in the 1949 Report.

If straw is to be heated after wetting, this should not be done for so long that it starts to dry out again as a result of heating. Four to seven days is usually enough to soften the straw and heat it enough.

The compost is much easier to handle if the straw is chopped before stacking. Some growers use a Robust Chopper for this purpose. After chopping, more compost can be packed in the bed, giving higher yields, and of course, more straw is needed per 1,000 sq. ft. The area filled by a ton of straw has been found to vary from 300 sq. ft. with chopped straw in an 8″ bed up to about 600 sq. ft. with longer straw and thinner beds.

Ready mixed MRA Activators are available from Messrs. Bradford Fertilizer Co. Ltd., Whitefield Place, Girlington, Bradford, Yorks.; Messrs. T. Elliott Ltd., Eagle Mills, 120 New Church Road, London, S.E.5; and Messrs. J. E. R. Simons Ltd., Natts Farm, Harlow, Essex.

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